Joint Analysis Group (JAG)

Review of *R/V Brooks McCall* Data to Examine Subsurface Oil

Background

This report presents a preliminary analyses of data collected by the R/V *Brooks McCall* near the site of the Deepwater Horizon MC252 (DWH-MC252) wellhead between May 8 and May 25, 2010. During this timeframe the DWH-MC252 wellhead was releasing gas and oil in a turbulent mixture from the broken riser pipe attached to the well. Throughout the data collection period, a plume of oil and gas continually rose from the wellhead with some oil reaching the surface in about three hours. During the trip to the surface, it is expected that some of the oil dissolved in the water column and some formed droplets. The pressure that propelled the oil out of the wellhead was strong enough to cause some of the oil to form water-in-oil emulsion, or mousse.

Dispersing oil at depth, either naturally or chemically, has the effect of breaking up the oil into small droplets within the water column. Because dispersed oil droplets vary in both size and buoyancy, droplets of different sizes take different lengths of time to rise to the water's surface. Very small droplets, less than about 100 µm in diameter, rise to the surface so slowly that ocean turbulence is likely strong enough to keep them mixed within the water column for at least several months.

As a requirement of the response effort of injecting chemical dispersants into oil being released from the well, ship-based water column sampling was undertaken from the R/V *Brooks McCall*. These data continue to be collected from the R/V *Brooks McCall* and its relief vessel the R/V *Ocean Veritas*. The period of data analyzed in this report extends from May 8 and through four cruises until May 25, 2010 (Fig. 1). During the time of these cruises, approximately 230,000 gallons of subsea dispersants were used. If the subsurface oil was successfully dispersed into small droplets, processes can result in oil remaining in subsurface waters, with horizontal transport potentially more than 10 km beyond the well.

Methods and Procedures

The R/V *Brooks McCall* was deployed to meet an EPA requirement to monitor subsurface dispersant use. The sample stations for oversight of dispersant use were not established in a regular pattern around the wellhead but were chosen based on the results from hydrodynamic modeling to anticipate the likely current flow field at depth

(primarily southwest axis from the well head). As evident in Figure 1, this initial sampling distribution left large spatial gaps and non-homogeneous observational data that limit conclusions that can be drawn about the full spatial extent of subsurface oil. It will be important and necessary in future analyses to integrate the full collection of data and observations from ships and other platforms from government, academic institutions, and privately funded operations.

During cruise 1 (May 8-12, 2010) the R/V *Brooks McCall* deployed a Sea-Bird Electronics, Inc., SBE 25 SEALOGGER CTD (Conductivity, Temperature and Depth) to measure temperature, salinity, and dissolved oxygen (DO_2), with Niskin water samples taken at 1-m, 275 m, and 550 m depth. A Sea-Bird 911 *plus* CTD with a Wet Labs ECO Colored Dissolved Organic Matter (CDOM) FLCDRTD-1800 fluorometer and a Sea-Bird SBE 43 DO_2 sensor to measure continuous profiles of temperature, salinity, DO_2, and fluorescence. In addition, bottle samples at 11 planned depths from the water surface to near seabed were used on Cruise 2 (May 15–17), Cruise 3 (May19–21) and Cruise 4 (May 23–25). Water samples were collected with a rosette of Niskin bottles. Two onboard measurements were made from these water samples: particle size using a LISST-100X particle counter and DO_2. In addition, collected samples were preserved for laboratory chemistry analyses for Total Petroleum Hydrocarbons (TPH) and Volatile Organic Analysis (VOA using EPA SW846 method 8260). Volatile organic compounds (VOCs), which have significant vapor pressures, can affect the environment and human health. No sampling was conducted closer than 1 km from the well during cruises 2–4 due to restrictions related to wellhead operations.

The results from measurements below the sea-surface mixed layer of approximately 150 m were examined by the Joint Analysis Group (JAG) to determine if there was evidence of subsurface oil and, if so, the concentration, location, and extent of that oil. Experimental data and simulation models of subsurface releases indicated that oil from the DWH-MC252 release would be expected at depth.

Data Analysis and Conclusions

The preponderance of evidence based on careful examination of the results from these four different cruises leads us to conclude that DWH-MC252 oil exists in subsurface waters near the well site in addition to the oil observed at the sea surface and that this oil appears to be chemically dispersed. While no chemical “fingerprinting” of samples was conducted to conclusively determine origin, the proximity to the well site and the

following analyses support this conclusion. These analyses should be revised and refined when additional higher resolution data from these four cruises become available and as results are derived from subsequent cruises.

- Fluorometry measurements show a reoccurring anomaly that first appears at approximately 1000 m and is attenuated between 1300 m and 1400 m deep. The fluorometric anomaly begins near the release area and trends primarily southwest, which is consistent with water movement along an isobath. (Figs. 2–8).

- Based on instrument response curves derived using LA Sweet Crude oil and provided by the manufacturer, fluorometer oil response data indicate a maximum concentration in the range of 34 ppm oil above background. See Fig. 10 for example stations B20 and B25 (background).

- Vertical fluorescence profiles show fine-scale structure distinguishable from background; the separation between the bottom of the fluorometry anomaly and the seafloor is clear (Fig. 9). This suggests that the fluorescence source is not CDOM from the seafloor.

- Taken as a whole, fluorometry, TPH, and VOA measurements indicate that the anomaly observed near the wellhead is consistent with oil associated with the spill site, this signal decreases with distance from the source, and it decreases towards the southwest beyond 10 km within the area sampled. Based on the droplet size distribution measurements from the LISST instrument, the data suggest that the small droplet diameters are consistent with chemically dispersed oil.

- Water sample analysis results for TPH show a correspondence with peaks in the *in-situ* fluorescence measurements at some stations. See in particular stations B30, B42-46, and B48-50 (Figs. 12, 24-28, 30-32).

- TPH concentration data are at or below concentrations of 2 ppm beyond the sea-surface mixed layer with a detection limit of about 0.8 ppm.

- Water-sample analysis results for Total Volatile Organic Analysis (TVOA) show a correspondence with peaks in the *in-situ* fluorescence measurements at some stations. In particular, see stations B34, B38, and B41 (Figs. 16, 20, 23).

- VOA concentration data show levels at or below 800 µg/L (ppb) beyond the sea-surface mixed layer.

- The water sample analysis for dispersed oil particles in the range of 2.5–60 µm using the LISST shows a correspondence with peaks in the *in-situ* fluorescence. See in particular stations B45-46, and B48-50 (Figs. 27-28, 30-32).

- Natural seeps in the immediate area could contribute in part to the fluorescence anomalies seen in the data.

- DO_2 levels in the water column are largely what are expected when compared with historical data (Figs. 35-42). Based on the CTD data, there is no evidence of large-scale changes in DO_2 levels (> 0.2 ml/L) in the water column at the time of sampling, which otherwise might indicate a response to increased biological activity.

- CTD DO_2 measurements show deviations and noise that begin at 1000 m and extend to the bottom. Preliminary analysis of the response suggests that the deviations and noise below 1000 m are instrumental issues rather than real DO_2 deviations.

- No indications of large-scale impacts on DO_2 levels corresponding with the fluorescence anomalies are found between 1000 m and 1400 m during the first 35 days of the spill. While large-scale hypoxia in the Northern Gulf of Mexico due to oil breakdown by microbes is not likely at present, the recently increased release estimates suggest scenarios where the oxidation could impact natural background levels of DO_2.

- DO_2 levels should continue to be monitored to understand the potential effects of increases in subsurface oil releases from the period of sampling referenced in these data.

- Preliminary analysis of the R/V *Brooks McCall* CTD cruise data shows that below the layer of most direct seasonal influence, the subsurface temperature and salinity data compare well with historical data as a function of depth.

- There is no evidence to suggest significant oil accumulation at density boundaries or discontinuities in the water column below the sea surface mixed layer.

- The spatial coverage of the samples is not uniform around the well head, and most of the samples after Cruise 1 were taken west–southwest of the well site and

within 15 km of the site. The full horizontal extent of the oil cannot be determined based on these data alone.

- A statistical correlation between TPH and VOA data with CDOM fluorescence cannot be determined at this time. Additional samples and analytical results will be necessary to determine if any correlation exists.
- This analysis does not consider or imply anything about the ecological consequences of the oil.

Oceanographic Setting

The location of the DWH MC252 well head is approximately 80 km southeast of the mouth of the Mississippi River, 40 km seaward of the shelf break, 120 km east of the Mississippi Canyon center, and at 1500 m depth. The vertical structure of temperature and salinity in the water column from recent R/V *Brooks McCall* observations is consistent with the range of historical vertical profiles in the vicinity of the well as available through the National Oceanographic Data Center (NODC).

From historical data: During May–June, the near-surface portion of the water column is being modified by increasing solar radiation. The mixed layer of approximately 150 m (nominally 18º C water) established during the previous spring and winter is being capped by the surface warming. Below 150 m, the temperature decreases to 4.5º C at the bottom. Surface salinity is variable at the site due to proximity to the Mississippi River plume, but a representative winter–spring surface mixed-layer salinity is approximately 36.2. Below the mixed layer, salinity decreases, and the water is nearly isohaline at approximately 34.9 below 700 m to the bottom. Variations in the annual density structure are confined to the upper 150 m. Dissolved O_2 maxima in the water column are above 80 m and contained within the nominal mixed layer of 150 m (> 3 ml/L above 150 m). DO_2 decreases below 150 m to a broad minimum in the water column of approximately 2.75 ml/L located at approximately 400–500 m. DO_2 concentrations increase below 450 m above 4.0 ml/L at 1000 m to bottom levels of about 4.9 ml/L.

The R/V *Brooks McCall* data were compared to measured *in-situ* observations (World Ocean Database—WOD) and climatological objectively analyzed (including mean and monthly-to-seasonal anomalies) values (World Ocean Atlas—WOA). Preliminary analysis of the R/V *Brooks McCall* CTD cruise data shows that below the layer of most

direct seasonal influence, the subsurface temperature and salinity data from cruise to cruise compare well with WOD and WOA data as a function of depth.

The DO_2 data derived from some of the casts from the R/V *Brooks McCall* cruises were relatively lower than WOA and WOD data, particularly below 1000 m depth. However, we believe that the lower values at depth are due to sensor issues (elaborated on below). On casts where no sensor problems were apparent, the R/V *Brooks McCall* casts are within the range of data represented in the WOA and WOD data sets.

Here we provide a brief synopsis of the DO_2 measurements from the *R/V Brooks McCall* Cruises 2–4. The focus is on the processed results from the DO_2 sensor connected to the CTD (SBE 43). This dataset is comprised of binned data (0.5 m resolution) from 33 stations that were obtained within about 15 km of the wellhead, with the majority of station within 4 km (Fig. 1).

It is important to measure DO_2 levels in the water surrounding the wellhead of the Deep Horizon spill because it can provide two important pieces of information:

1. Decreasing DO_2 concentrations could be indicative of oxidation of the oil with these decreases potentially impacting ecosystem health.
2. DO_2, along with temperature and salinity, serves as an important water mass tracer in the interior of the ocean.

Overall the results from the SBE 43 probe correspond well with the historical data in the vicinity as provided in the WOA database (Fig. 43). However, we did not have at hand concurrent, discrete, high quality, DO_2 measurements that could be used to validate the spatial and temporal CTD DO_2 data.

Interpretation

Large-scale features

Based on the profiles there is no evidence of large-scale changes in DO_2 levels (>0.2 ml/L) in the water column. The profiles are largely what are expected compared to the historical comparison.

Small-scale features

In several instances, the increase in fluorescence corresponds to an approximately 0.2 ml/L decrease in DO_2 (Fig. 44). This decrease could be an effect of oxidation of oil or

a spurious sensor response to adsorption of oil on the membrane. In either case it provides a rough and very qualitative impact of the oil on the sensor, or DO_2, in the water column.

General Assessment

Based on the 33 stations taken near the leaking wellhead, there was no indication of large-scale impacts of the oil on DO_2 levels during the first 35 days of the spill. The largest changes observed by the sensor were about 0.3 ml/L, which at this time, we do not believe are true O_2 signals. If such a decrease occurred in the DO_2 minimum layer at 400 m with concentrations of about 2.7 ml/L, then the values would still be above what is generally considered hypoxic (1.4 ml/L or 2.0 mg/L). We therefore do not believe that the threat of large-scale hypoxia as a consequence of [microbially-mediated] oxidation near the wellhead at this time is a likely occurrence. However, simple calculations using the higher estimates (6/10/2010) for the amount of oil released of 1.3 million gallons/day suggest O_2 levels could decrease approximately 10 % in the deep water if a significant fraction of oil remains subsurface and the rate of dispersion of the oil is low.

Notes on Fluorometry

The SBE 911*plus* is equipped with a Wet Labs ECO CDOM FLCDRTD-1800 fluorometer that can operate to a maximum of 6000 m. The instrument is used to detect fluorescence from a broad spectrum of chemical compounds (excitation 370 nm, emission 460 nm, sensitivity 0.09 ppb of a laboratory standard, range 0–500 ppb), and is not specific to fluorescence from petroleum hydrocarbons. The instruments are calibrated at the factory with quinine sulfate dihydrate (QSde), and the concentrations quoted above are for QSde, not crude oil. The manufacturer recently completed a response curve using three concentrations of South Louisiana Light Sweet Crude Oil. The curves suggested a minimum detection limit (MDL) of about 1 ppm for South Louisiana Crude Oil (Fig. 45).

The CDOM crude oil response curve from the manufacturer demonstrated that the sensor could detect parts per million concentrations of oil. Using the manufacturer's response curve and accounting for background values of fluorescence from a station outside the plume (B25), the maximum value within the *RV Brooks McCall* CTD data set of 40 ppb QSDE at Station B20 corresponds to about 34 ppm oil. The 34 ppm value should only be interpreted as an approximate indicator until more complete instrument calibration and response data are available.

Notes on Chemical Analysis

The Total Petroleum Hydrocarbon (TPH) method is a modified method for detection of semivolatile petroleum hydrocarbons. The method involves a methylene chloride extraction of a whole water sample (usually about 1 L), with the extract then quantified using a UV/VIS detector. The minimum detection limit (MDL) for this method was about 0.8 ppm TPH. For samples with detectable amounts of TPH, verification of the source oil was conducted by concentrating extracts and reanalyzing them with a Gas Chromatograph/Mass Spectrometer (GC/MS). Polycyclic aromatic hydrocarbons (PAHs) are also quantified using the GC/MS analysis.

Total volatile organic concentrations (TVOA) are defined as the sum of the priority pollutant analytes (i.e., the 8260 analyte list) along with the: "Tentatively Identified Compounds" (TICs). The common petroleum hydrocarbons found include benzene, toluene, ethylbenzene, xylenes, etc. The TICs identified include straight-chain alkanes (e.g., propane, butane, pentane), branched alkanes (e.g., isobutene), along with cyclic alkanes, etc. These compounds were quantified as an estimated concentration based on surrogates added to the mixture given their responses are reasonably equivalent.

At the time of this report VOA data were only available for a subset of the stations occupied during Cruises 2, 3, and 4. The analysis in this report only considered VOA analysis from Cruises 3 and 4. Unfortunately, the depths at which bottle samples were taken on Cruise 2 were not recorded so that TVOA results from that cruise cannot be directly compared with fluorometry and LISST data.

Notes on Sampling

The nature of sampling with Niskin bottles presents some potential for sampling errors. Niskin bottles are open as they pass through the sea surface. The bottles are open on the transit to the bottom and then triggered to close en route to the surface. There is a potential for oil to remain inside of Niskin bottles as they traverse the water column both at the surface and at depth. This oil could cause measured VOA and TPH measurement to be too high at shallower depths. It might also account for TPH values at 500 m and 200 m seen at some stations (i.e., B42 and B47).

Oil droplets rise; their ascent rate depends upon their size. The protocol does call for an inspection of the water surface for sheening within the Niskin bottle, but the appearance

of a sheen might not be sufficient to account for oil droplets rising within the bottle or sticking to the inside of the bottle during the time between sampling the water and transferring the samples to glass bottles for TPH measurements. Droplet rise and oil adhering to the surface of the Niskin bottle could cause TPH measurements to be artificially low. LISST data did not find variations in particle size distributions between the middle and top of Niskin bottle samples.

An additional issue with regards to this data set is that water samples were collected at fixed depths. Fluorometer measurements showed high variability through the 1000 m to 1400 m zone when fluorescence was detected. Therefore, the exact vertical location of water samples does not always correspond to areas of high CDOM fluorescence. It is possible that when TPH values were below the minimum detection limits (MDLs) for samples with significant fluorescence peaks, the water sample could have missed the fluorescing material.

Notes on Oxygen Measurement

A composite of the last 10 stations is provided in Figure 46. An interesting aspect is the decreased sensor response of about 0.2 ml/L below 1000 m for several of the casts. The rapid decrease suggests a sensor artifact rather than a real DO_2 decrease, particularly because there are no associated changes in temperature, salinity, or fluorescence at these depths. The depth at which the decrease occurs differs for different casts. The data shown in Figure 46 are processed data for downcasts. Figure 47 shows a trace for upcast and downcast for Station 31. During the downcast, the signal decreases by 0.2–0.3 ml/L at 1000 m and turns noisy. This offset and noise remains on the upcast up to about 550 m, at which point it merges with the downcast trace. The manufacturer, Sea-Bird Electronics, is investigating possible causes for these variations and agrees with our assessment that it is likely caused by sensor malfunction.

The accuracy of the SBE 43 sensor on the CTD was checked during the cruise by taking samples from 11 bottles tripped for each profile and then analyzing the samples using a "Lamotte kit" or with a handheld probe. The low resolution and accuracy of these validation methods render them useless for accurate calibration (at the level of 0.02 ml/L). Based on the reproducibility of the SBE 43 probe on the CTD for the subsequent stations and correspondence with historical data (Fig. 43), we believe that the SBE 43 sensor faithfully represents the DO_2 content and water-column features at the sampling stations.

Development of this Report

The JAG was recognized formally by the National Incident Command (NIC) on June 8, 2010, subsuming work that had been proceeding on an *ad hoc* basis motivated by the need to synthesize available information on subsurface sampling. The JAG operated at two levels for the production of its findings. For purposes of information exchange and metadata development, the group includes industry representatives responsible for providing data from contracted ships. For the purposes of final report development and approval of findings, just the federal agency representatives are involved. This report is the first in an anticipated series of data products from the JAG concerning data from the spill related to subsurface sampling.

Members of the Joint Analysis Group appointed to date:

FEDERAL MEMBERSHIP

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Dr. Robert Pavia, Contractor, NOAA Office of Response and Restoration, Seattle, WA (Deputy Lead)
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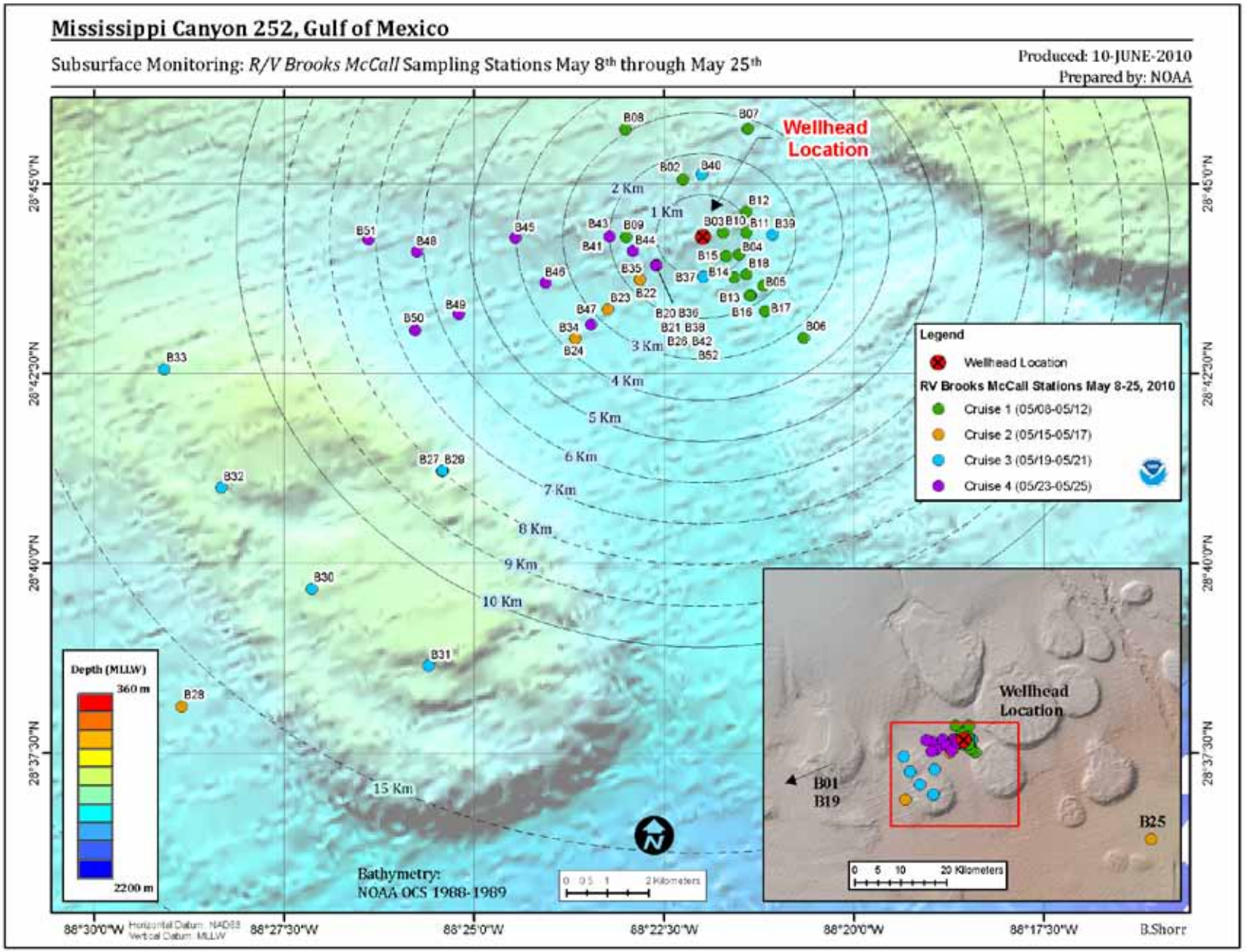
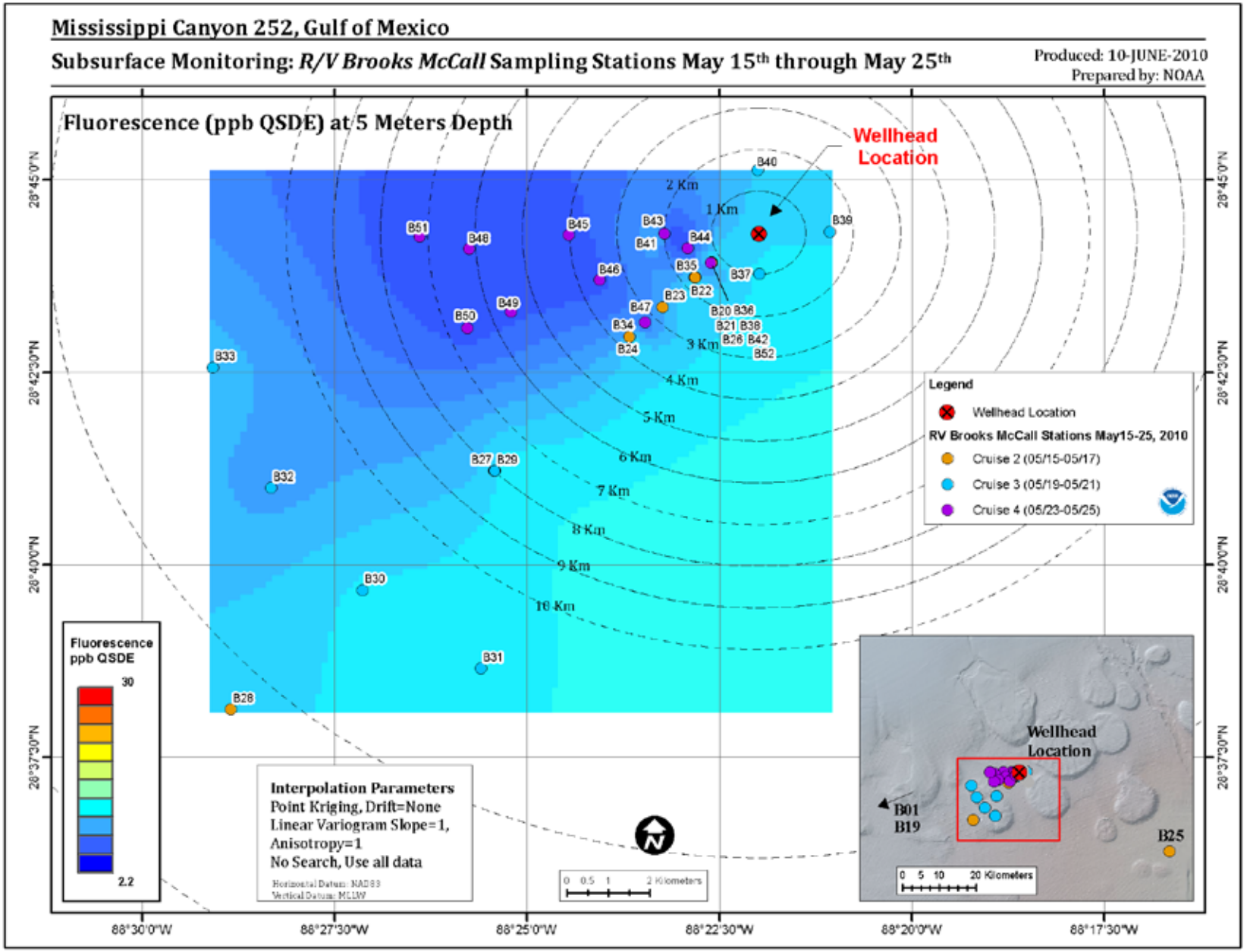
Figure 1. Location of sampling stations for *R/V Brooks McCall* Cruises 1-4.



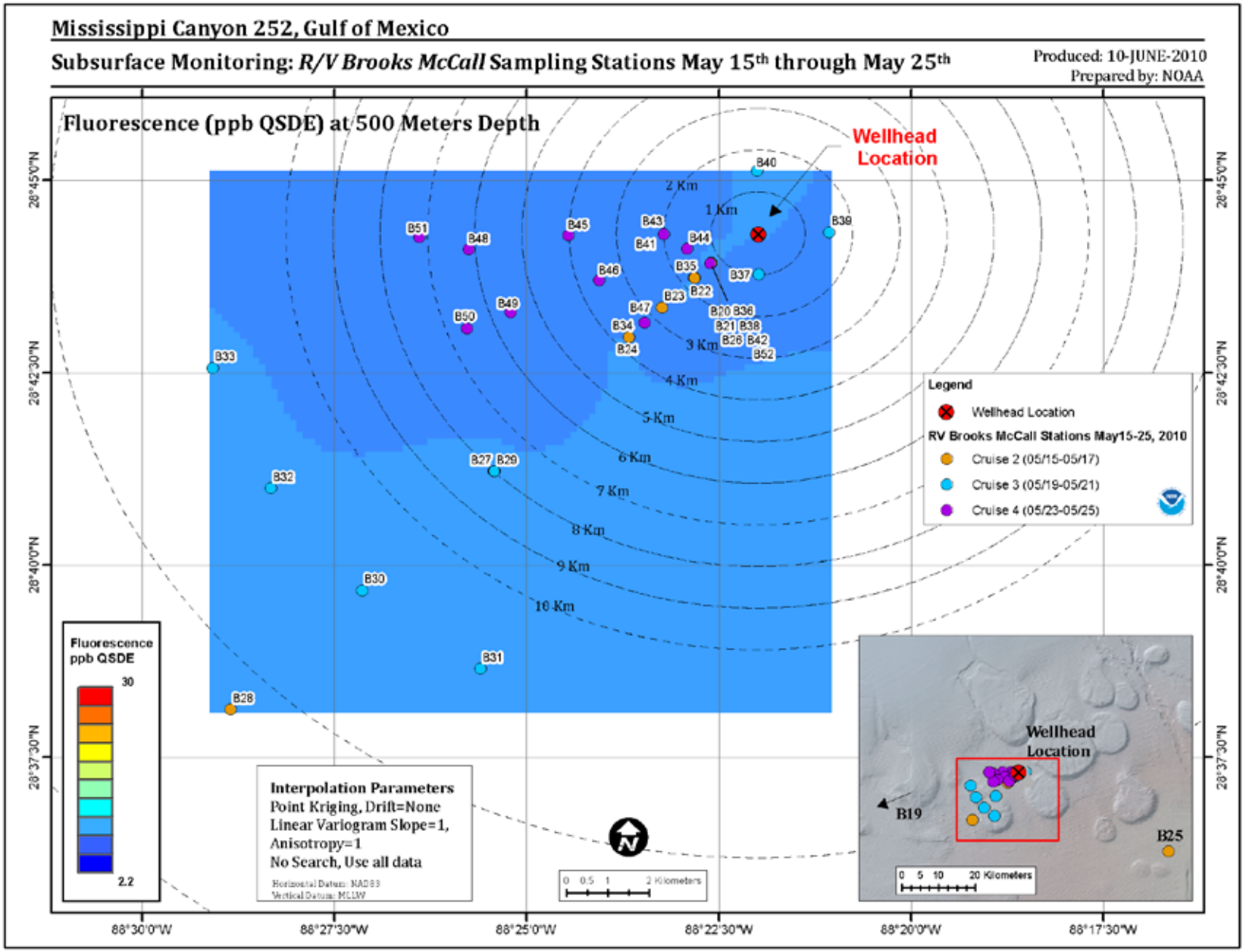
Preliminary Data Subject to Change

Figure 2. Fluorescence data from cruises 2-4 contoured at 5 meter depth. This figure shows measurements taken over an 11 day period.



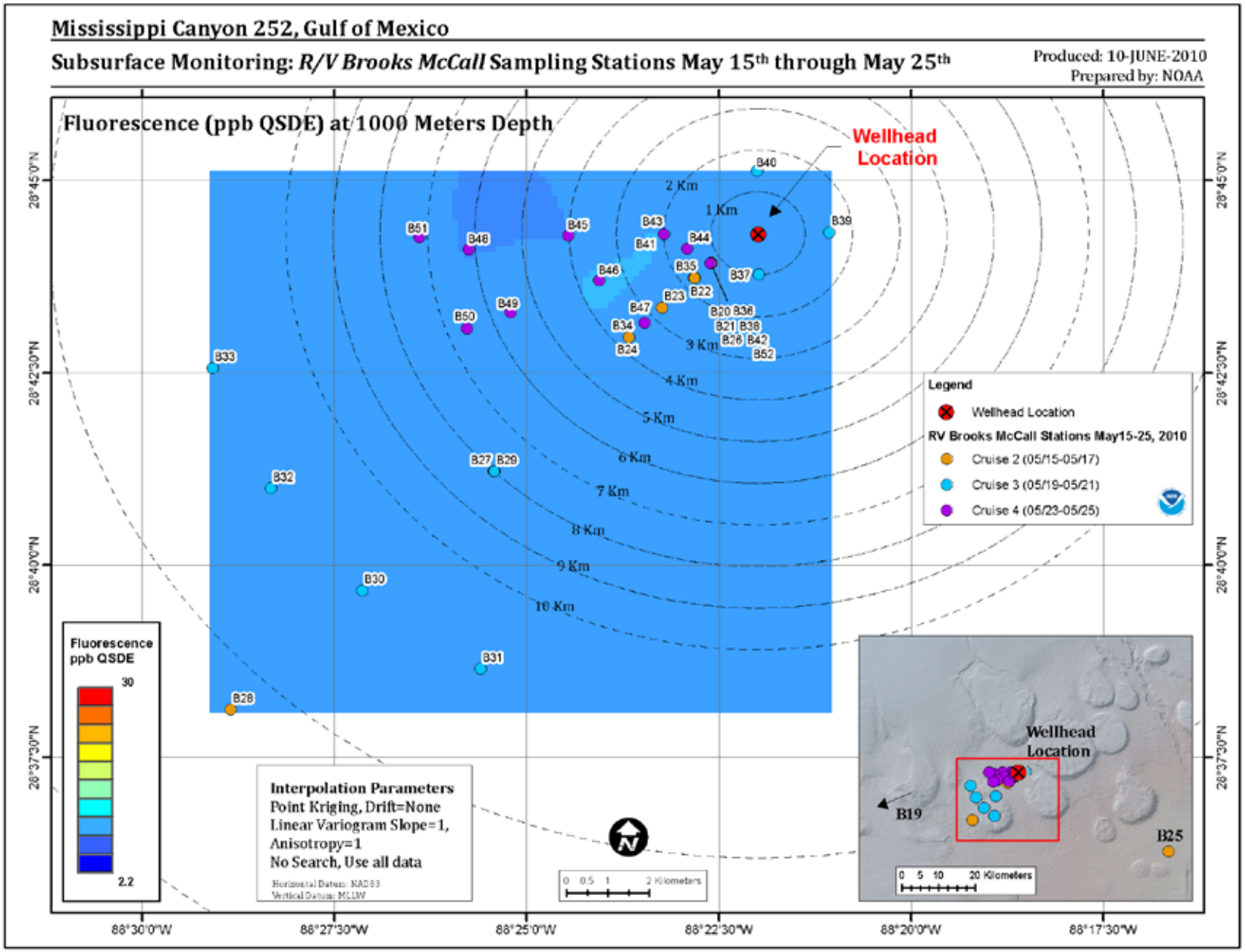
Preliminary Data Subject to Change

Figure 3. Fluorescence data from cruises 2-4 contoured at 500 meter depth. This figure shows measurements taken over an 11 day period.



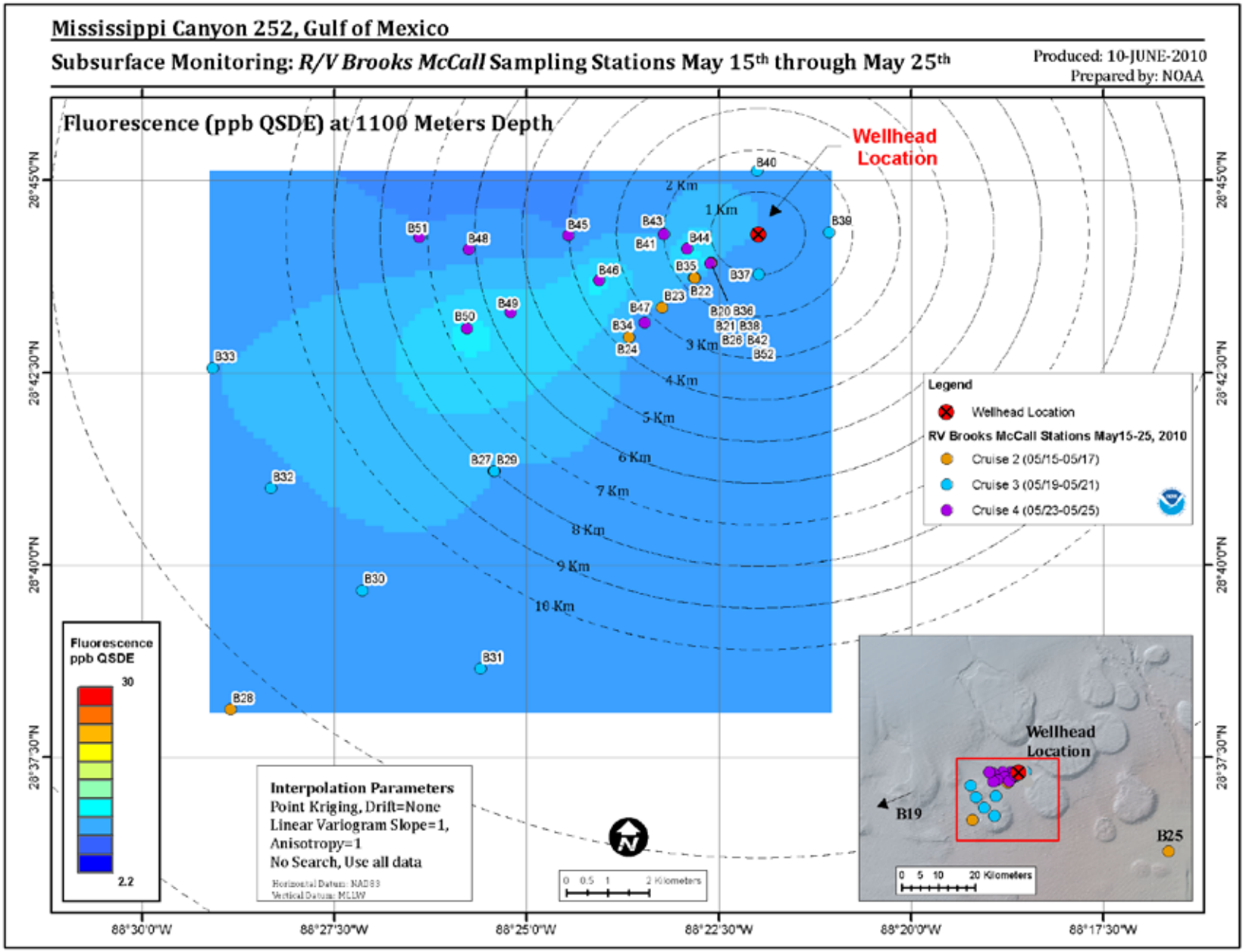
Preliminary Data Subject to Change

Figure 4. Fluorescence data from cruises 2-4 contoured at 1000 meter depth. This figure shows measurements taken over an 11 day period.



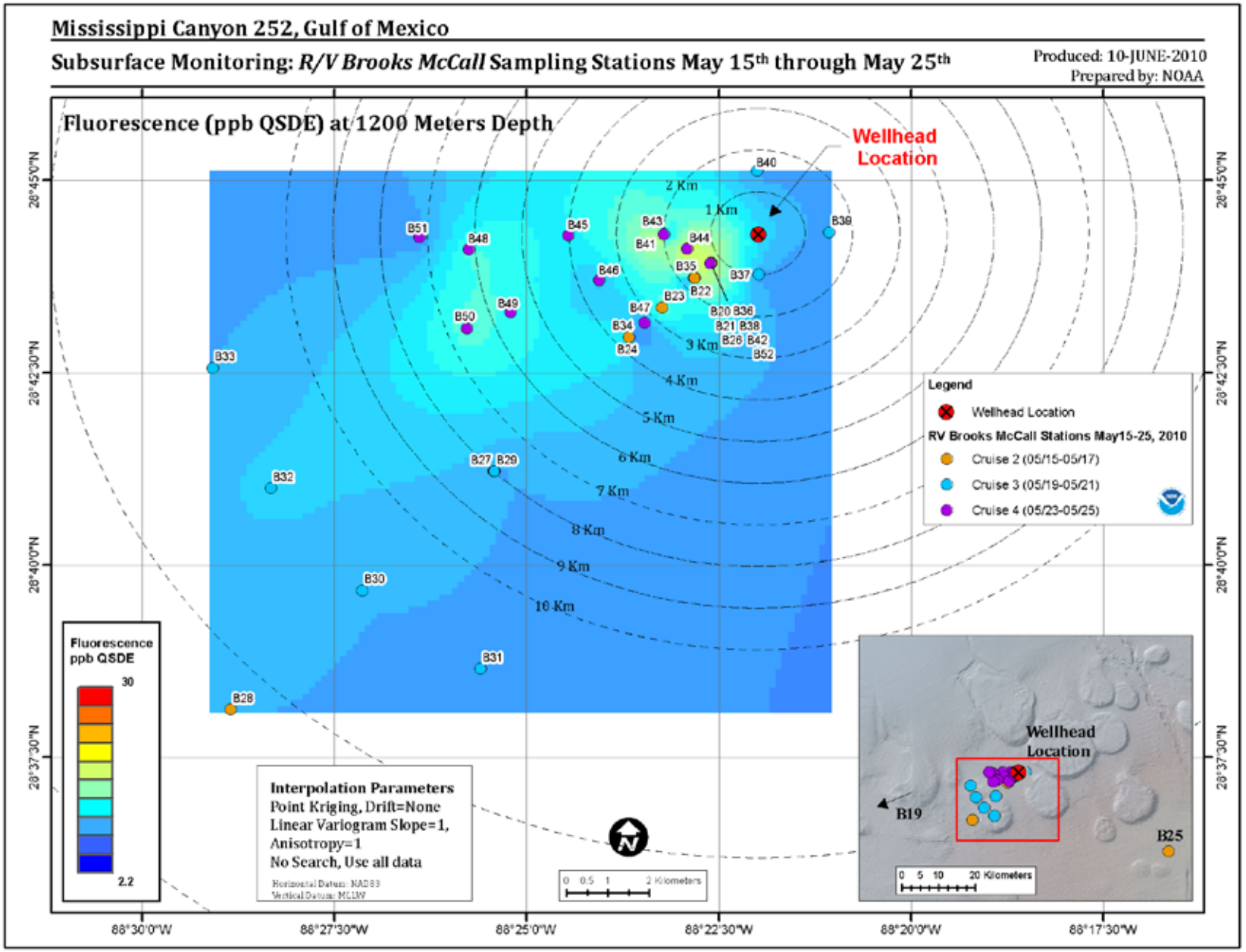
Preliminary Data Subject to Change

Figure 5. Fluorescence data from cruises 2-4 contoured at 1100 meter depth. This figure shows measurements taken over an 11 day period.



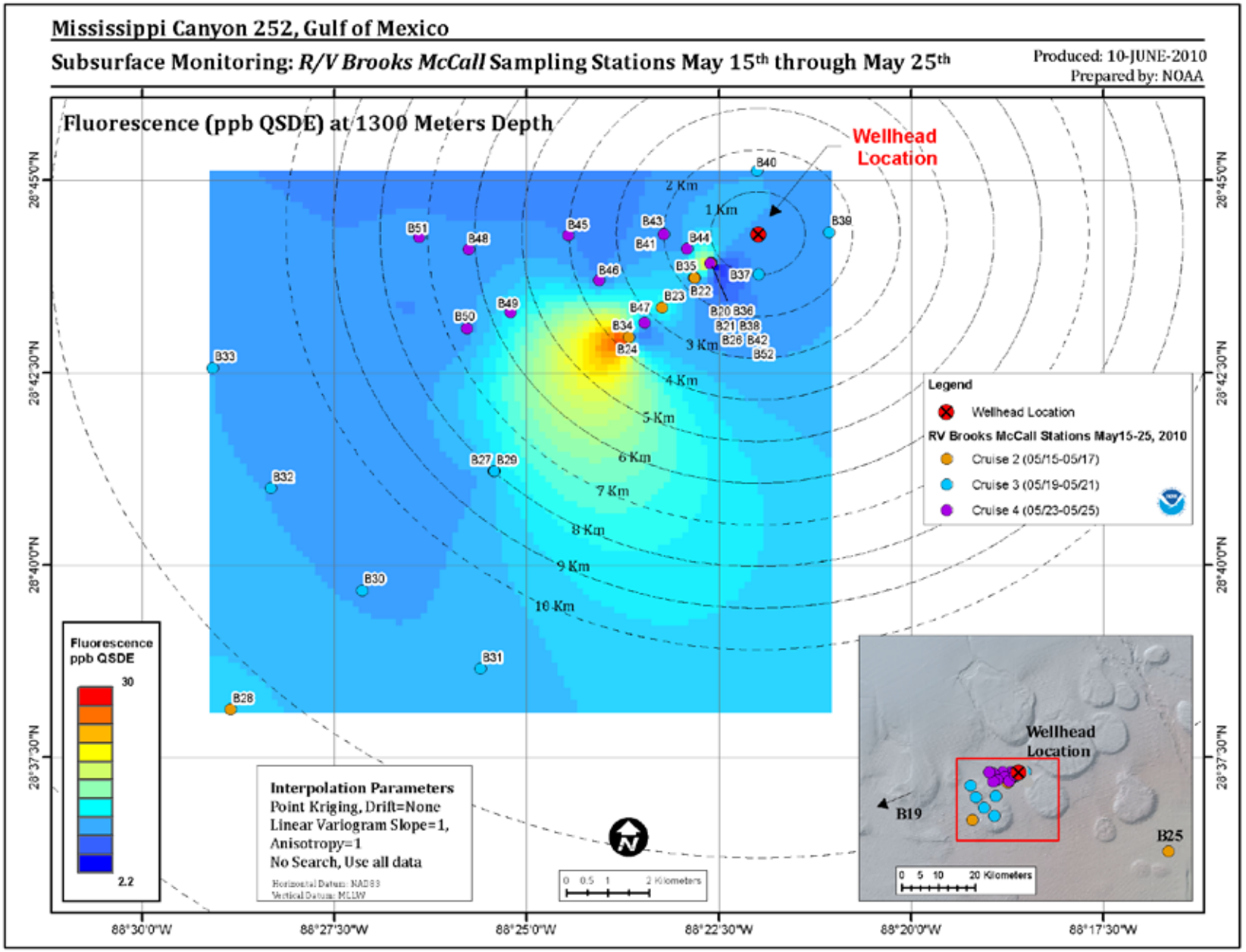
Preliminary Data Subject to Change

Figure 6. Fluorescence data from cruises 2-4 contoured at 1200 meter depth. This figure shows measurements taken over an 11 day period.



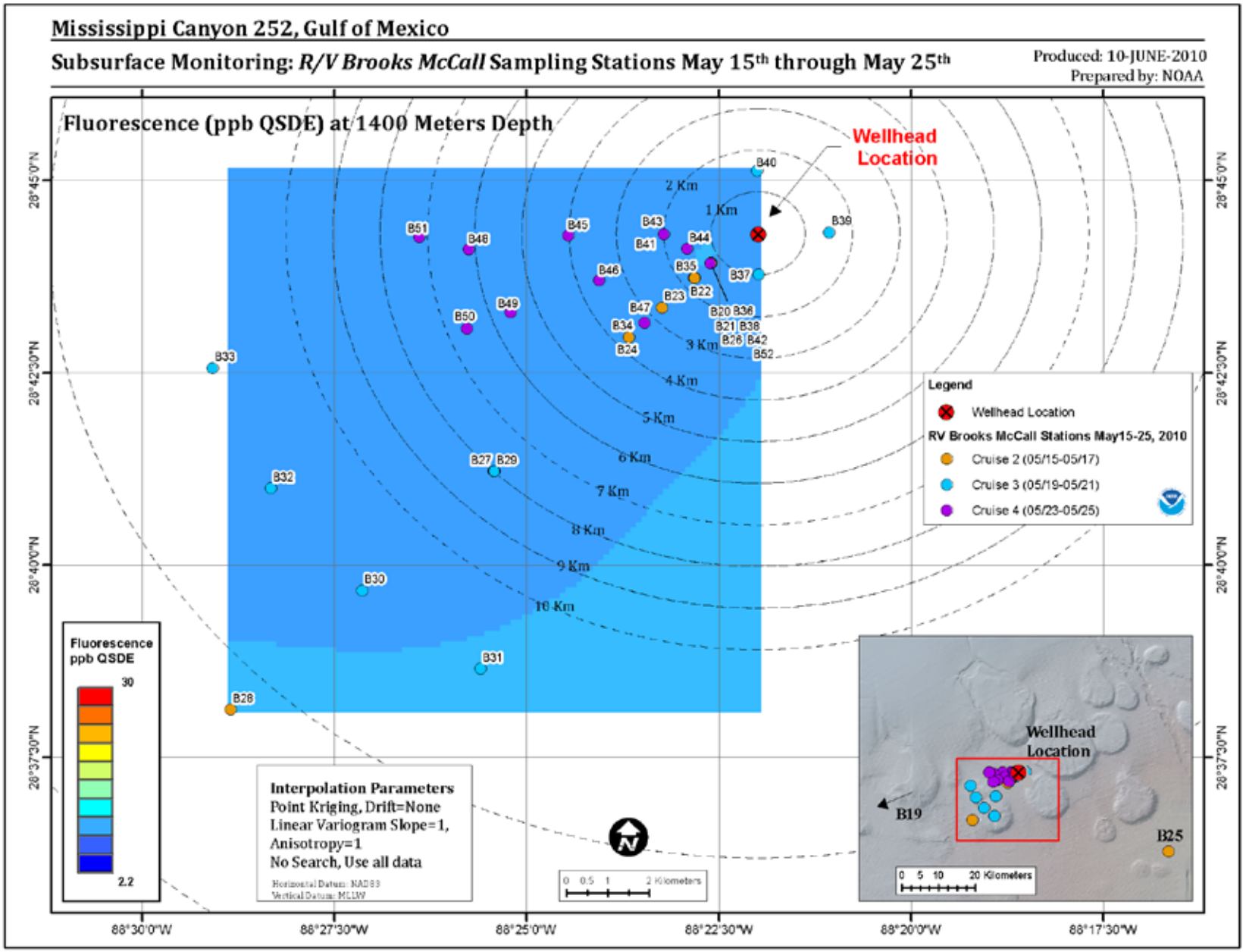
Preliminary Data Subject to Change

Figure 7. Fluorescence data from cruises 2-4 contoured at 1300 meter depth. This figure shows measurements taken over an 11 day period.



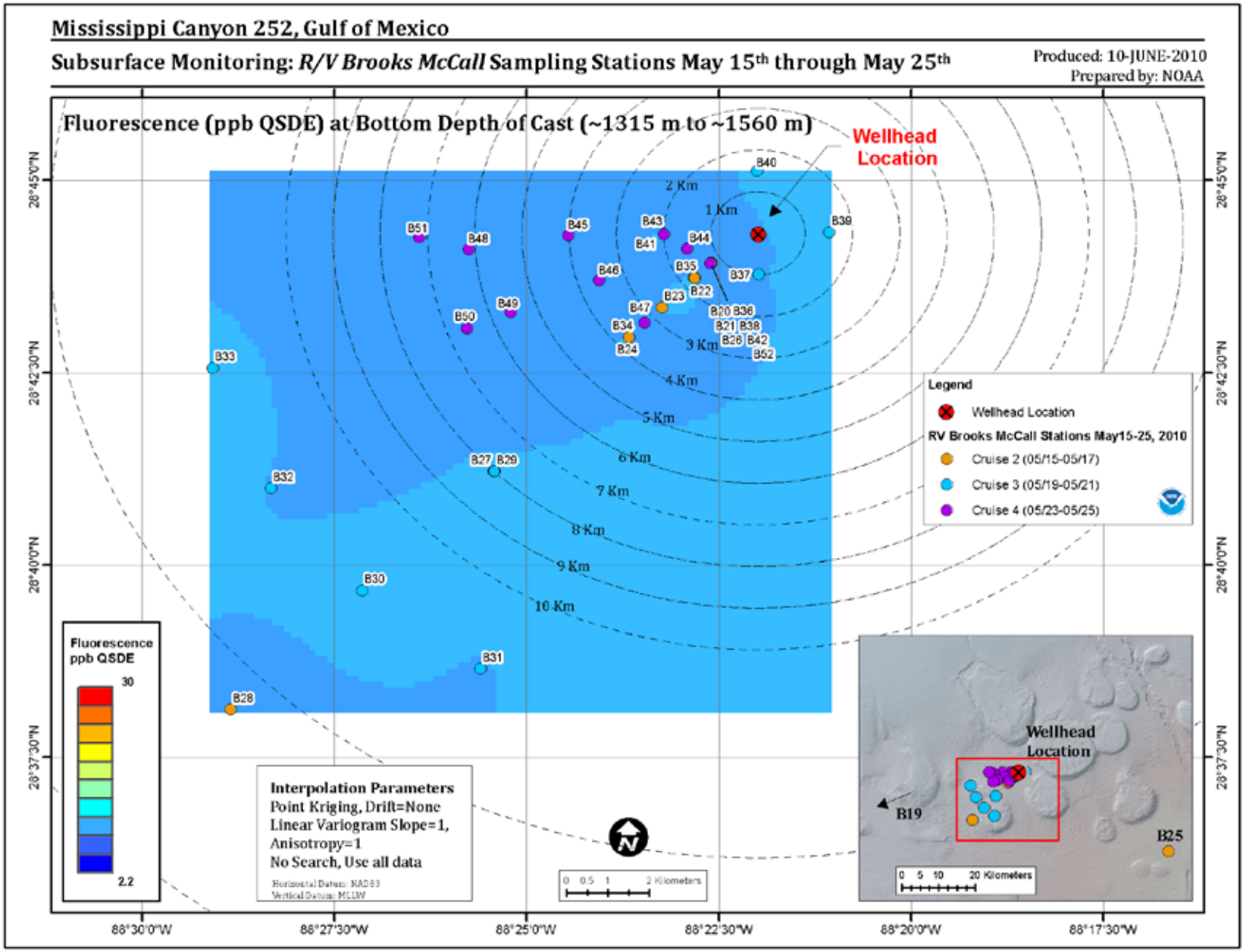
Preliminary Data Subject to Change

Figure 8. Fluorescence data from cruises 2-4 contoured at 1400 meter depth. This figure shows measurements taken over an 11 day period.



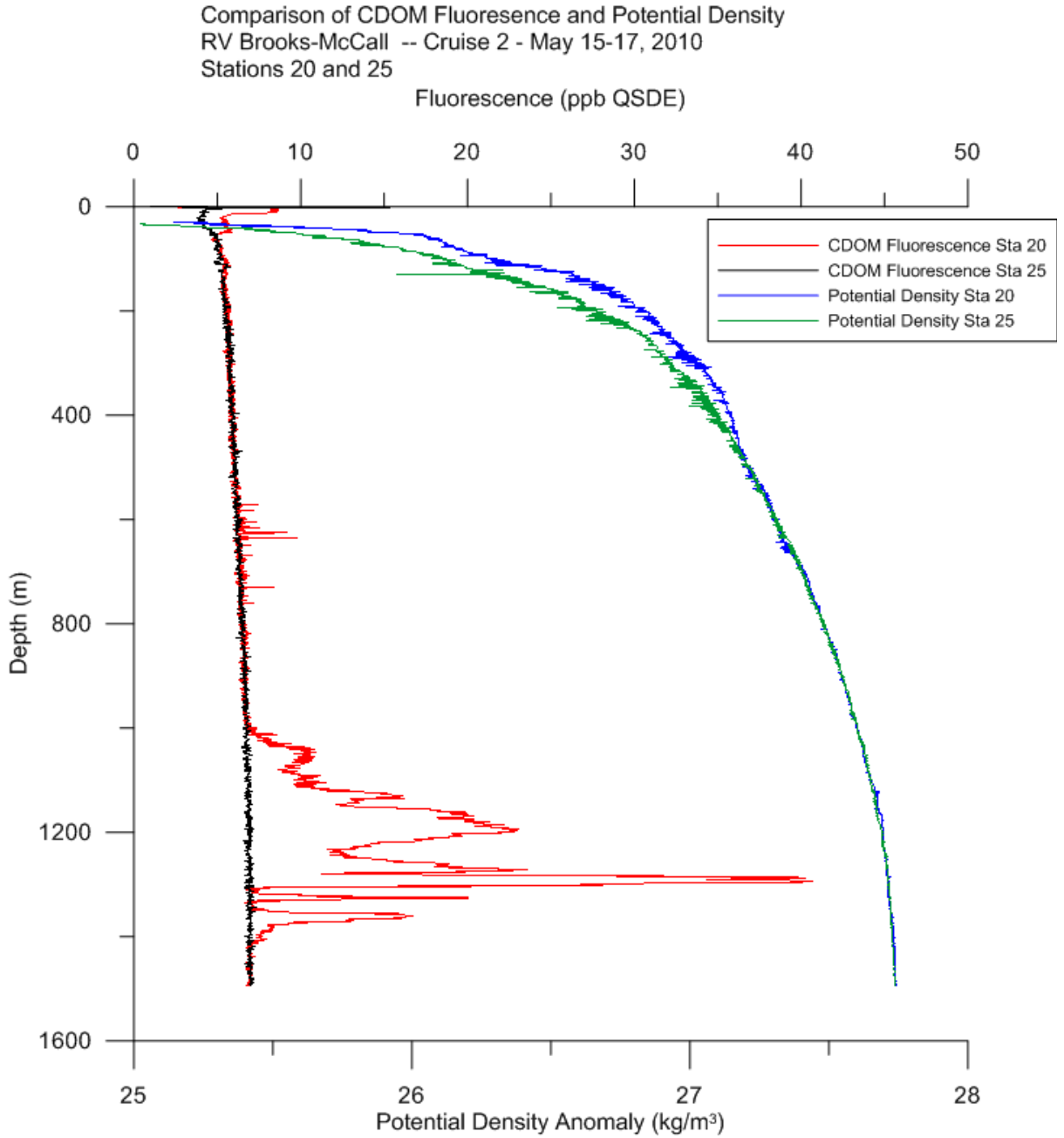
Preliminary Data Subject to Change

Figure 9. Fluorescence data from cruises 2-4 contoured at bottom depth. This figure shows measurements taken over an 11 day period.



Preliminary Data Subject to Change

Figure 10. Fluorescence from station B20, the highest value at any location compared to station B25 a reference site more than 30 km to the southeast.



Preliminary Data Subject to Change

Figure 11. Vertical Profile of fluorescence and oxygen measurements from a CTD cast at station B29 shown with LISST and laboratory analytical data from Niskin Bottle samples.

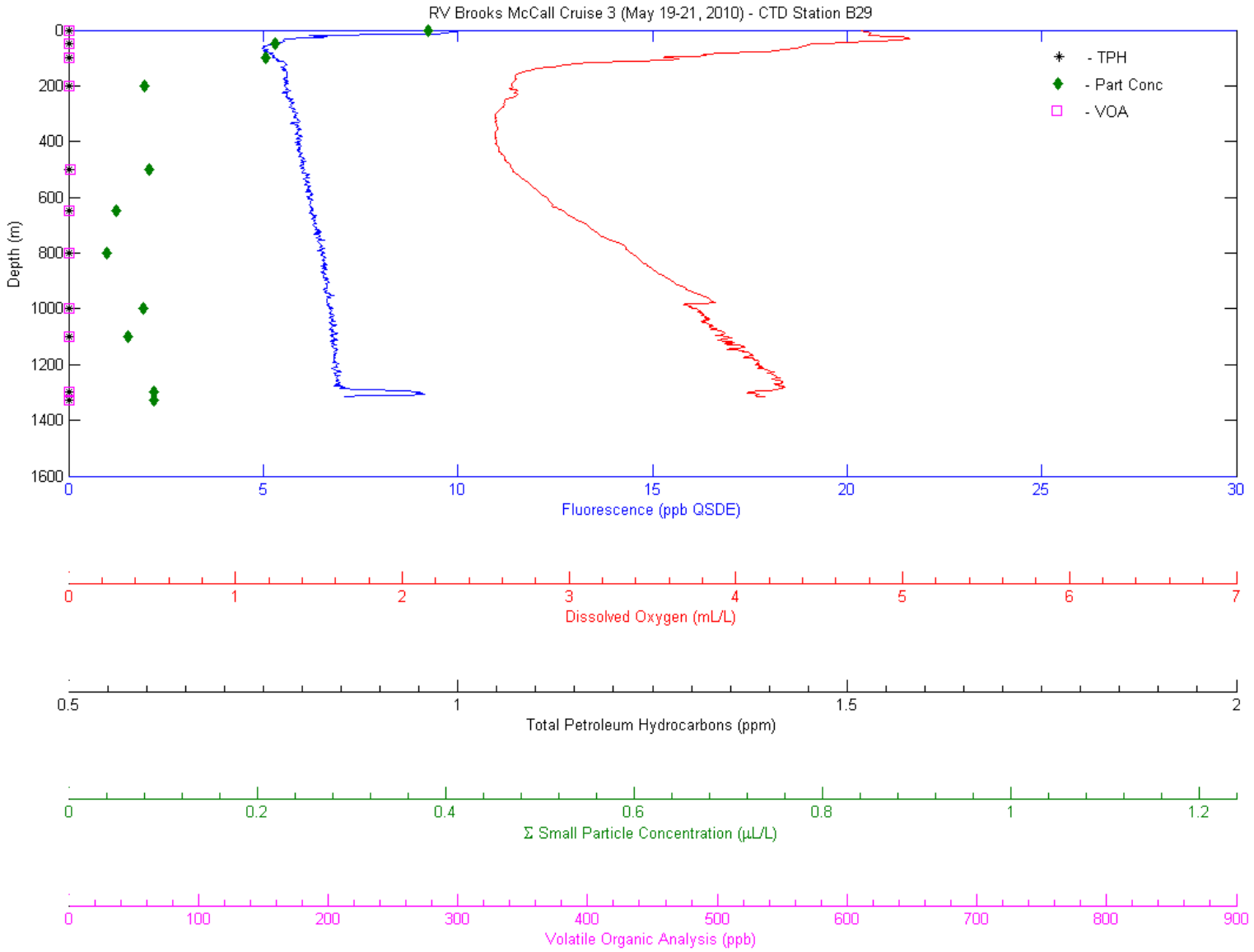
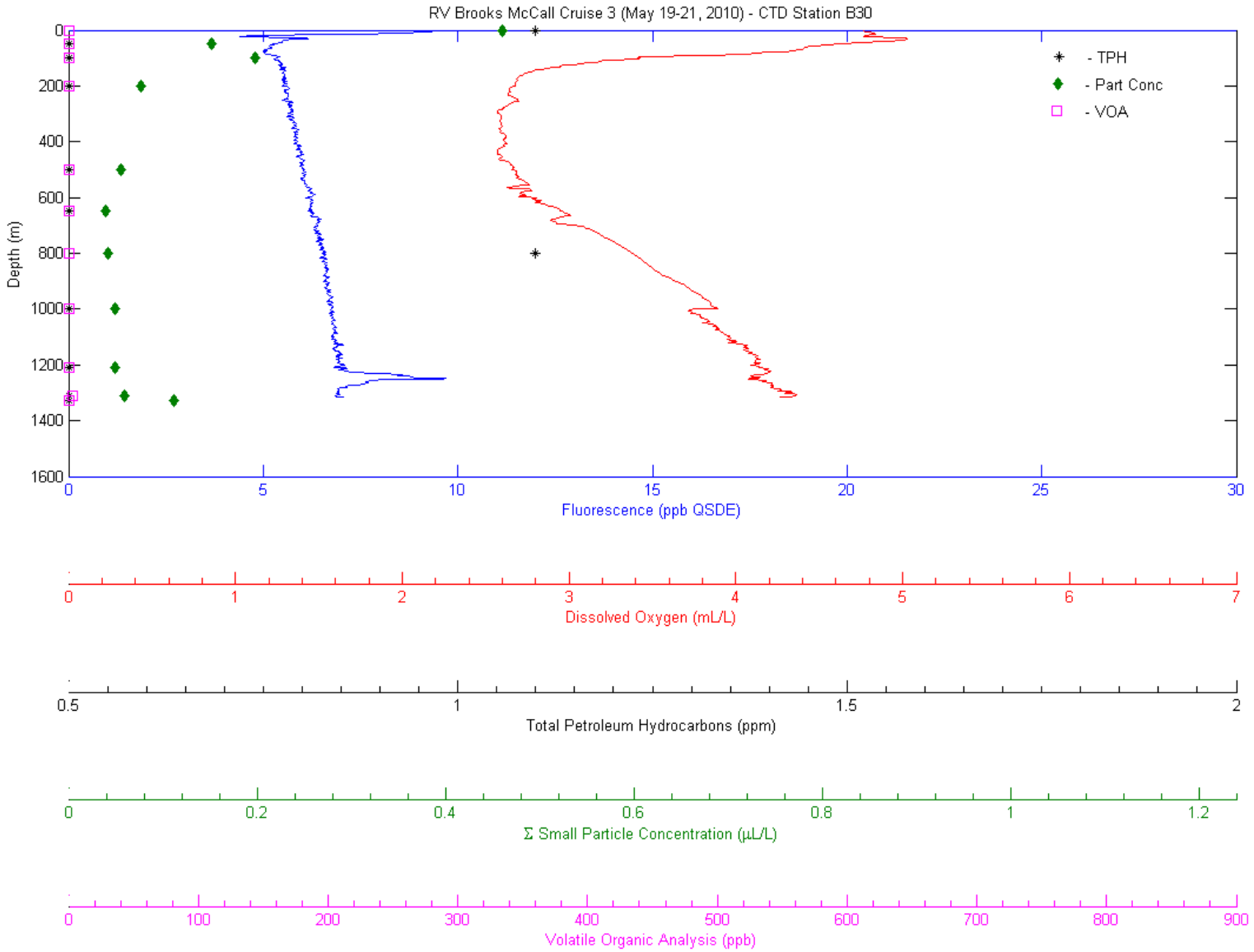


Figure 12. Vertical Profile of fluorescence and oxygen measurements from a CTD cast at station B30 shown with LISST and laboratory analytical data from Niskin Bottle samples.



Preliminary Data Subject to Change

Figure 13. Vertical Profile of fluorescence and oxygen measurements from a CTD cast at station B31 shown with LISST and laboratory analytical data from Niskin Bottle samples.

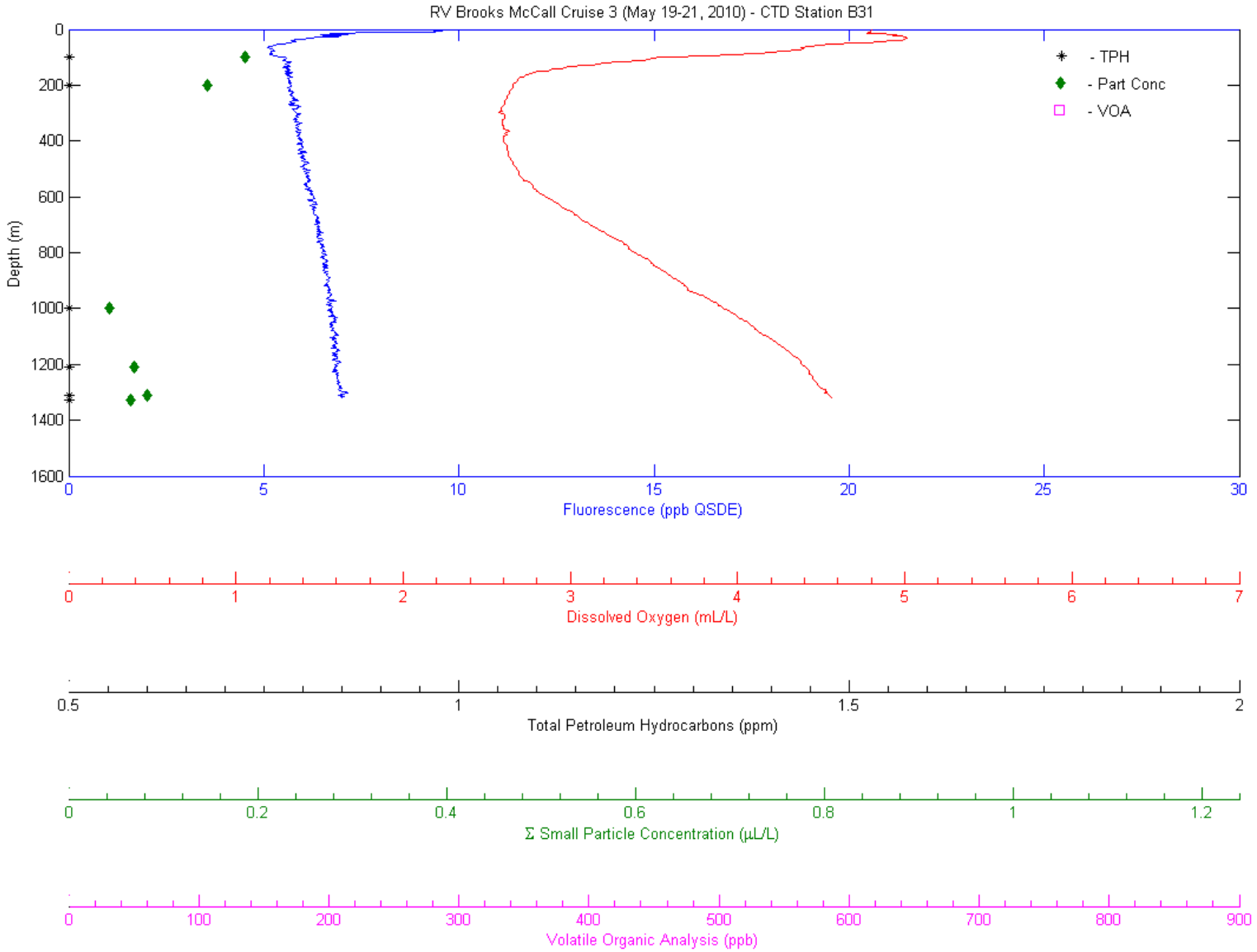


Figure 14. Vertical Profile of fluorescence and oxygen measurements from a CTD cast at station B32 shown with LISST and laboratory analytical data from Niskin Bottle samples.

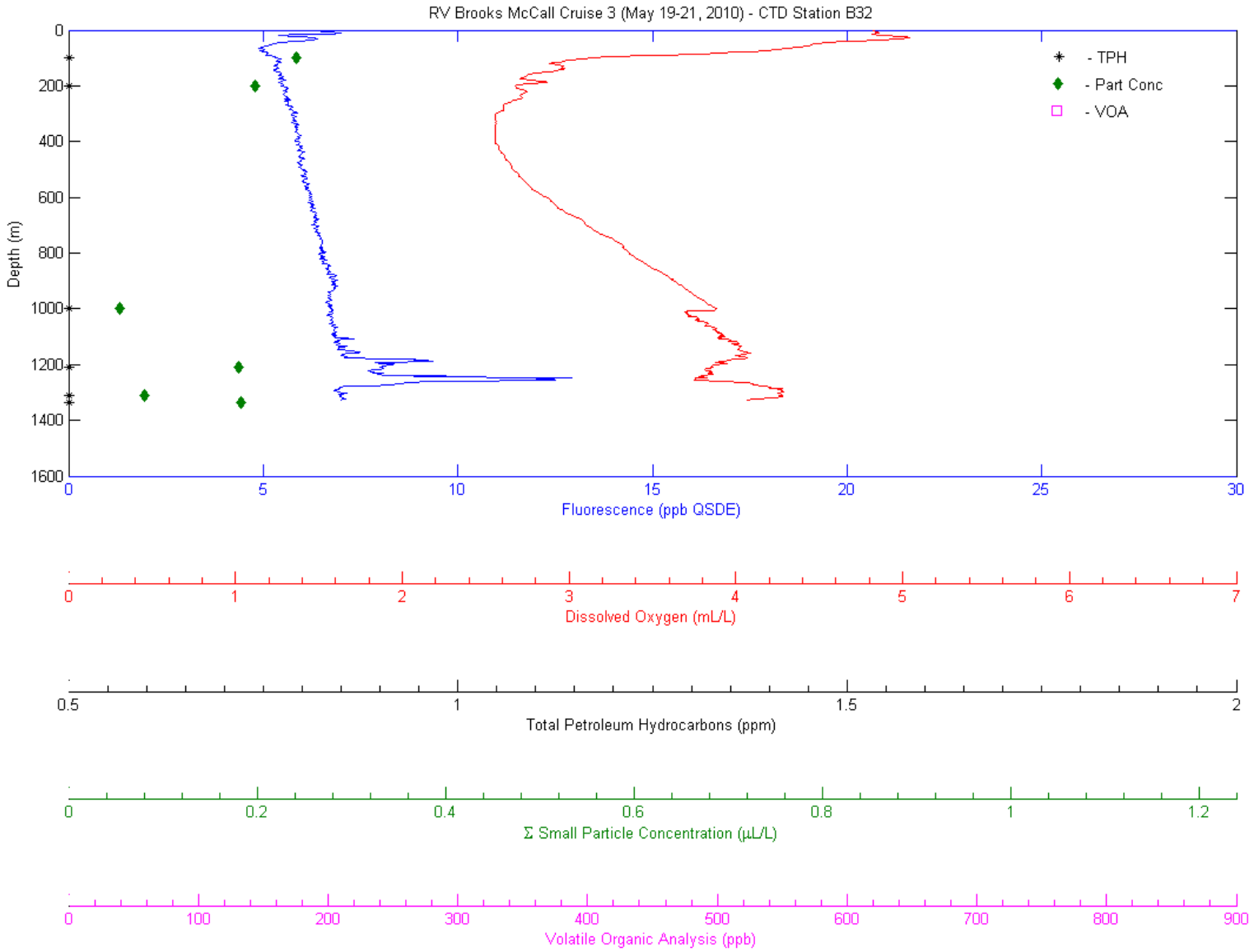


Figure 15. Vertical Profile of fluorescence and oxygen measurements from a CTD cast at station B33 shown with LISST and laboratory analytical data from Niskin Bottle samples.

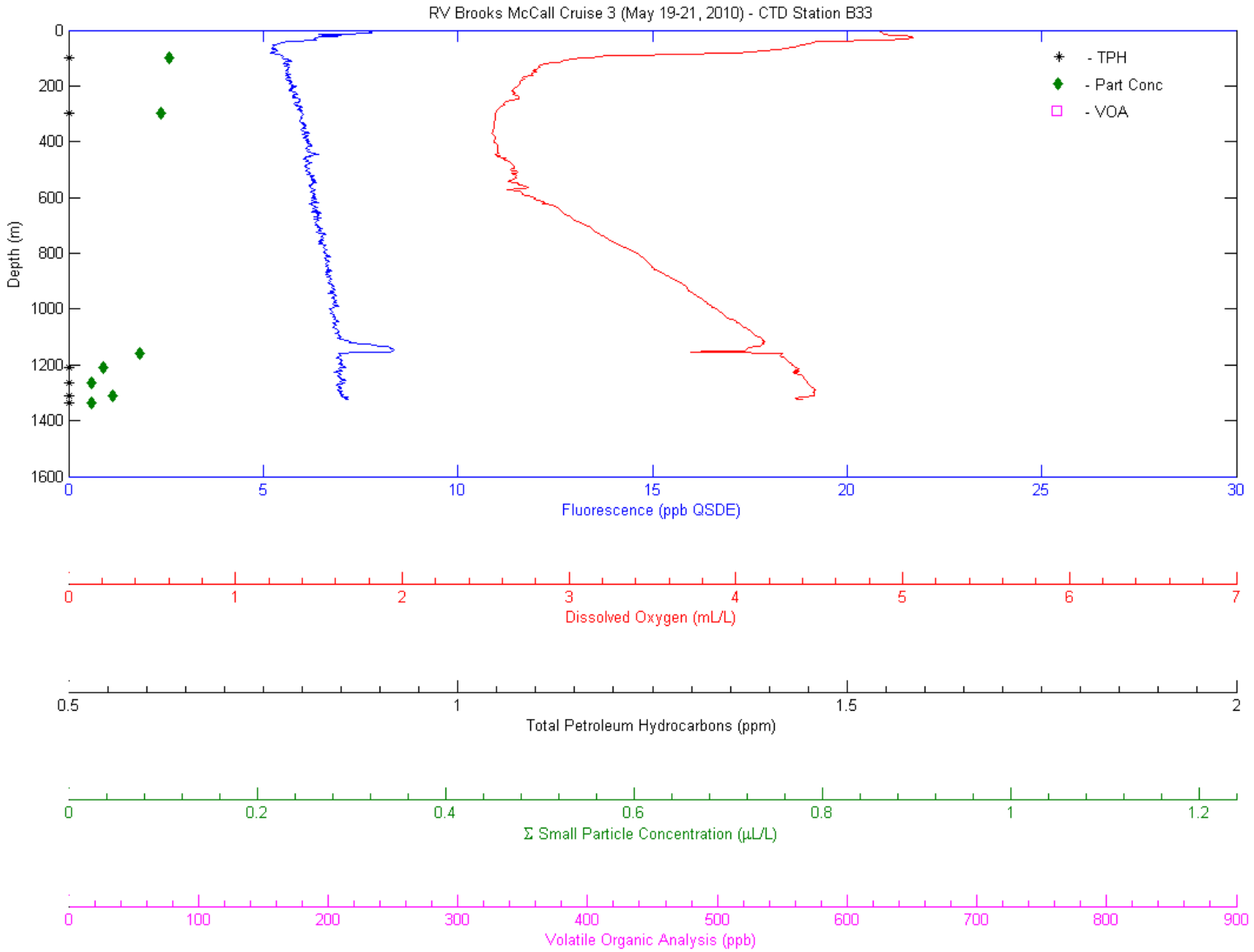
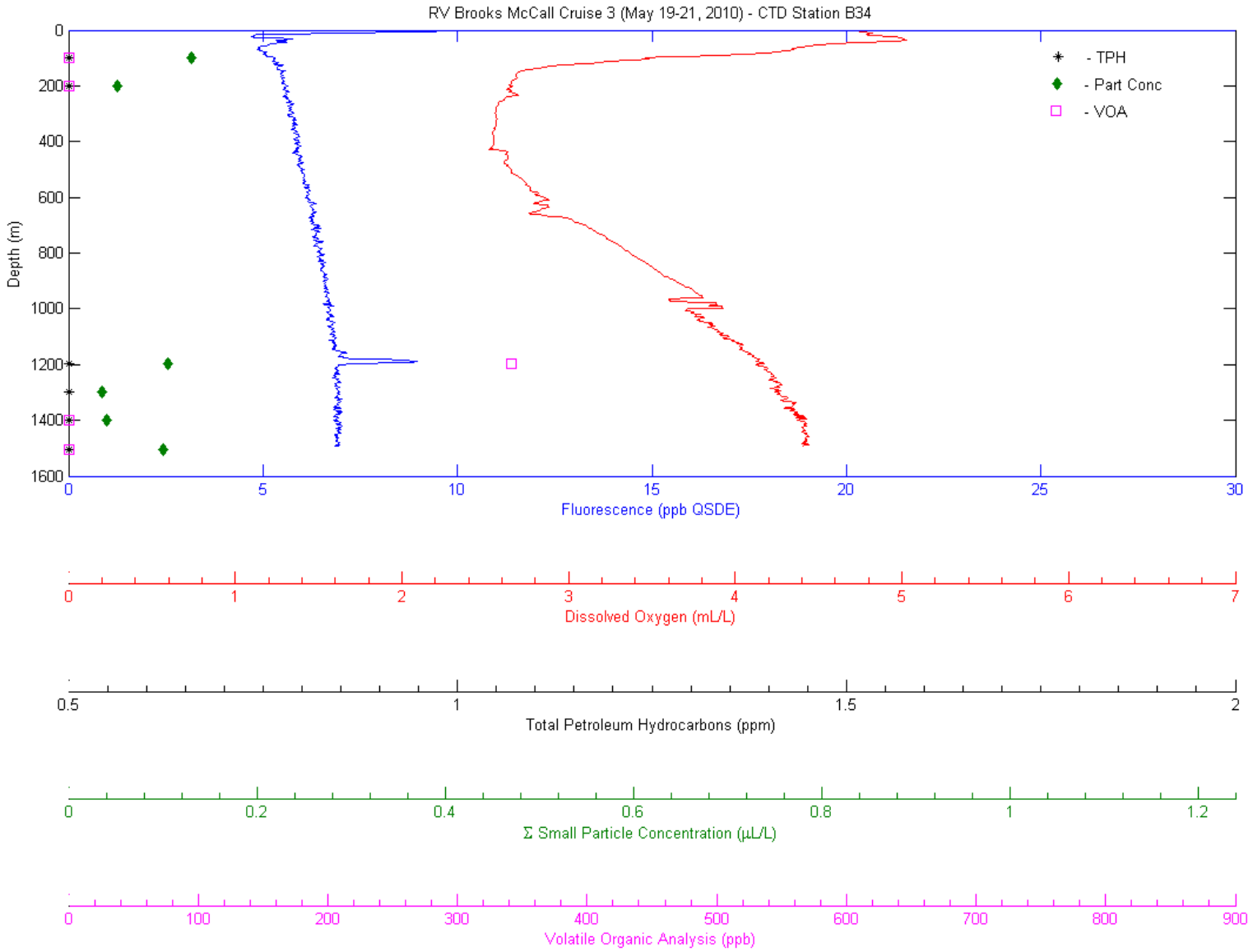


Figure 16. Vertical Profile of fluorescence and oxygen measurements from a CTD cast at station B34 shown with LISST and laboratory analytical data from Niskin Bottle samples.



Preliminary Data Subject to Change

Figure 17. Vertical Profile of fluorescence and oxygen measurements from a CTD cast at station B35 shown with LISST and laboratory analytical data from Niskin Bottle samples.

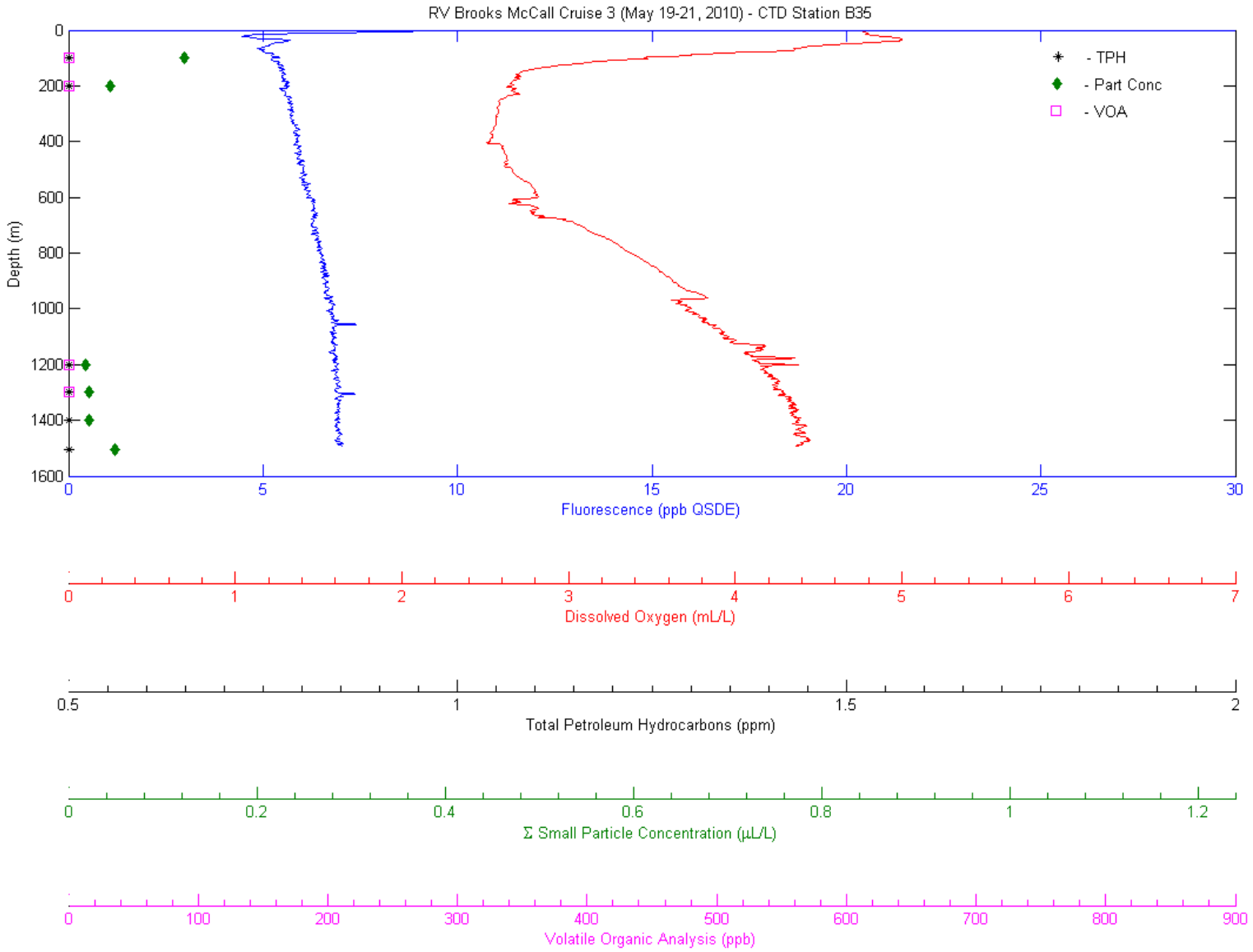
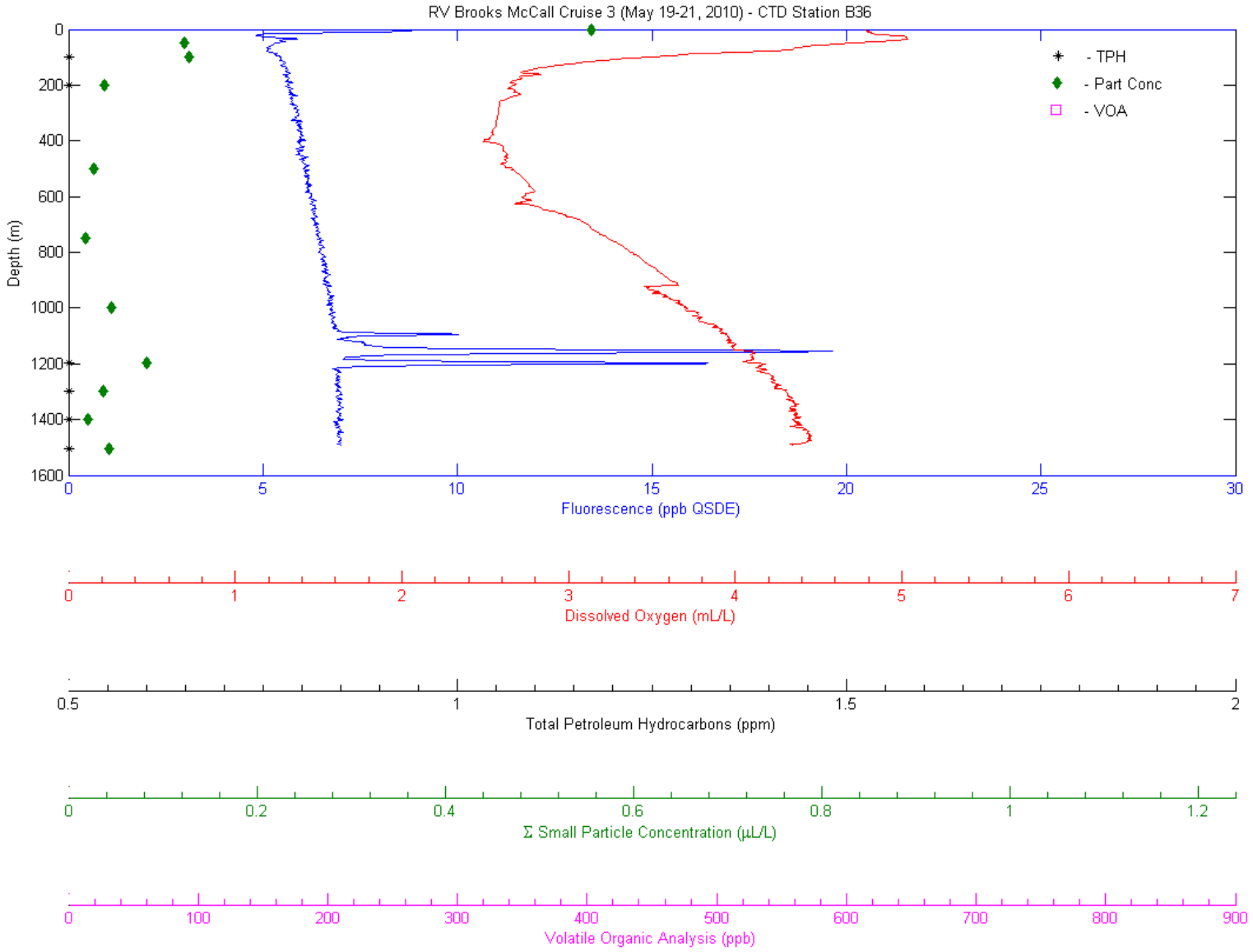


Figure 18. Vertical Profile of fluorescence and oxygen measurements from a CTD cast at station B36 shown with LISST and laboratory analytical data from Niskin Bottle samples.



Preliminary Data Subject to Change

Figure 19. Vertical Profile of fluorescence and oxygen measurements from a CTD cast at station B37 shown with LISST and laboratory analytical data from Niskin Bottle samples.

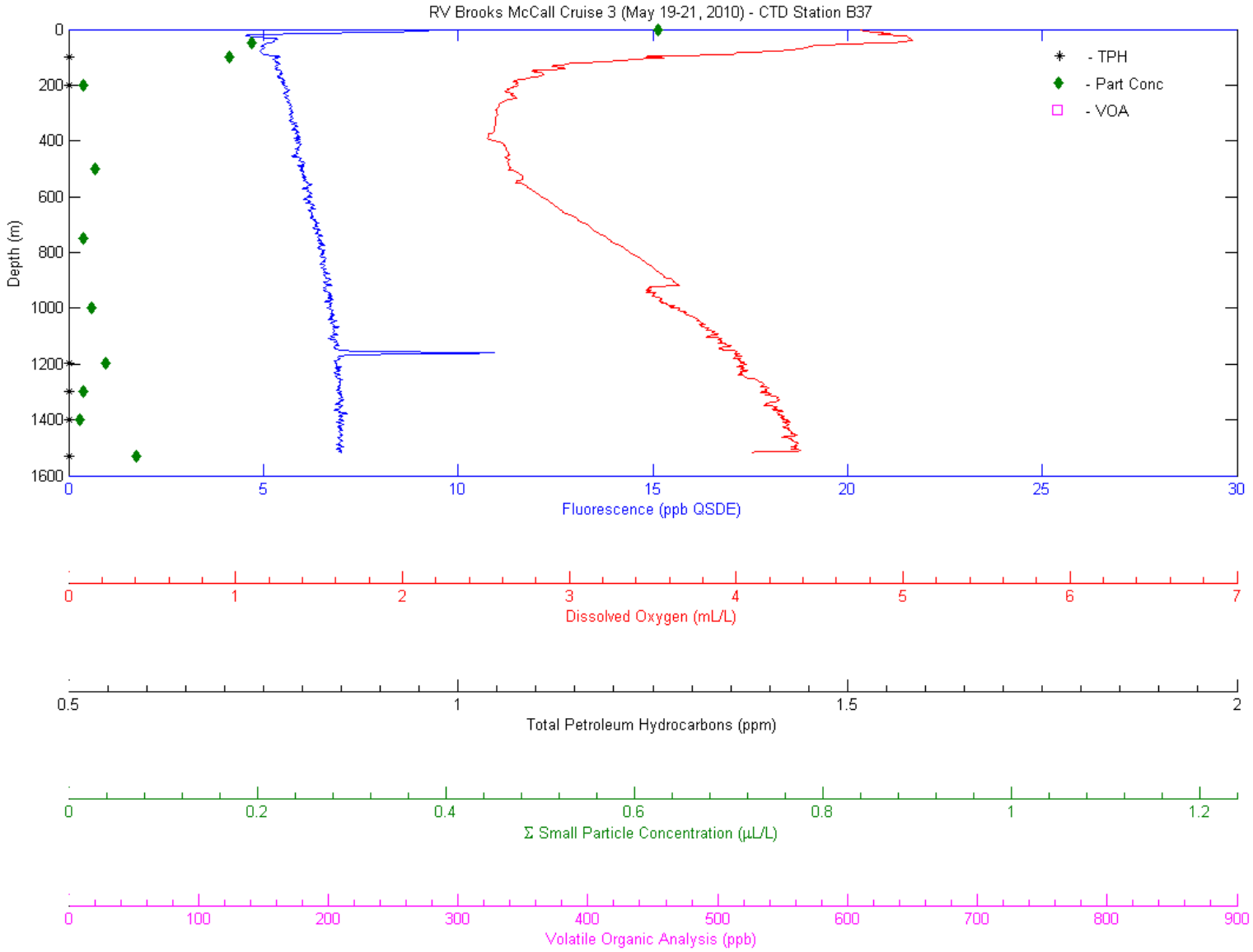


Figure 20. Vertical Profile of fluorescence and oxygen measurements from a CTD cast at station B38 shown with LISST and laboratory analytical data from Niskin Bottle samples.

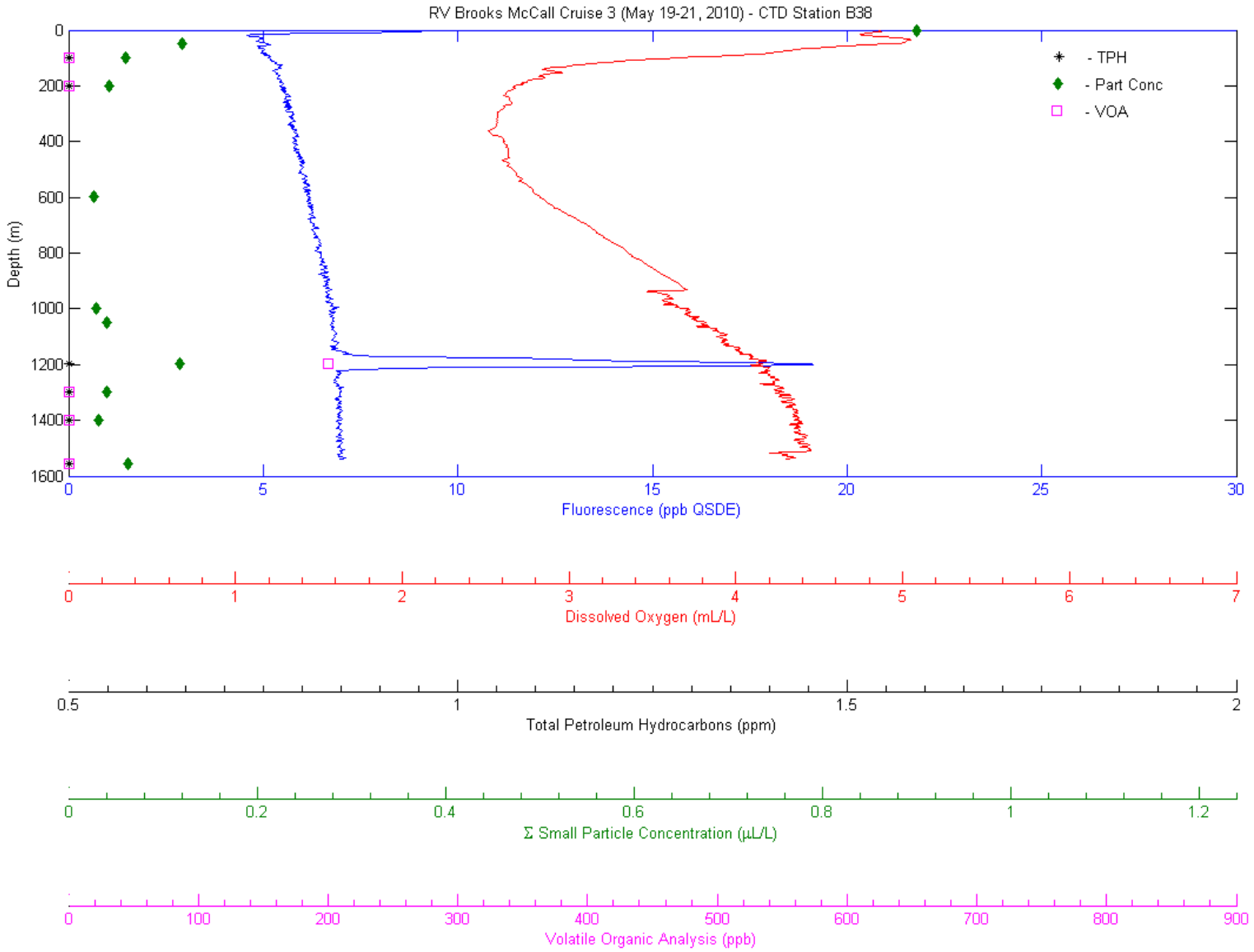
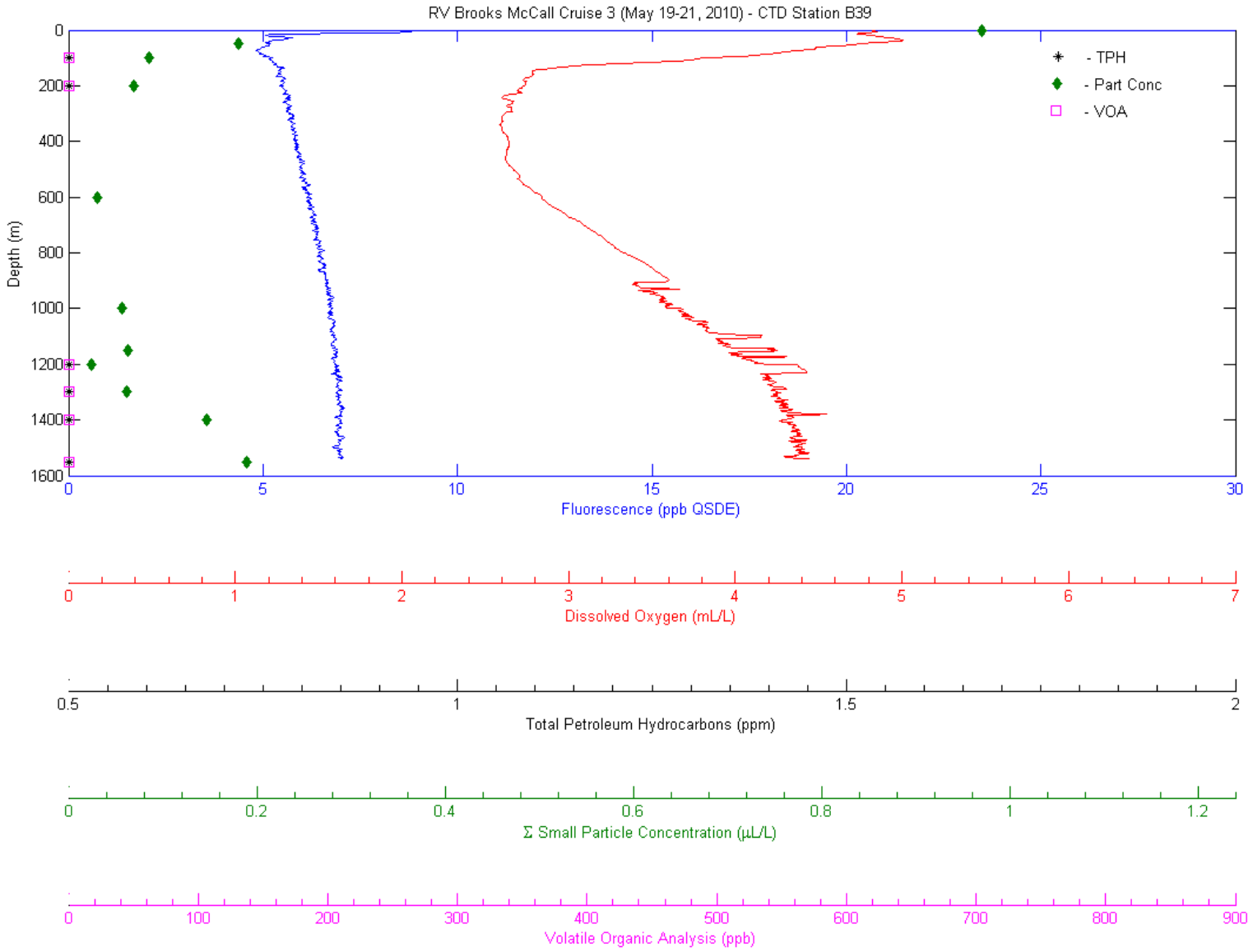


Figure 21. Vertical Profile of fluorescence and oxygen measurements from a CTD cast at station B39 shown with LISST and laboratory analytical data from Niskin Bottle samples.



Preliminary Data Subject to Change

Figure 22. Vertical Profile of fluorescence and oxygen measurements from a CTD cast at station B40 shown with LISST and laboratory analytical data from Niskin Bottle samples.

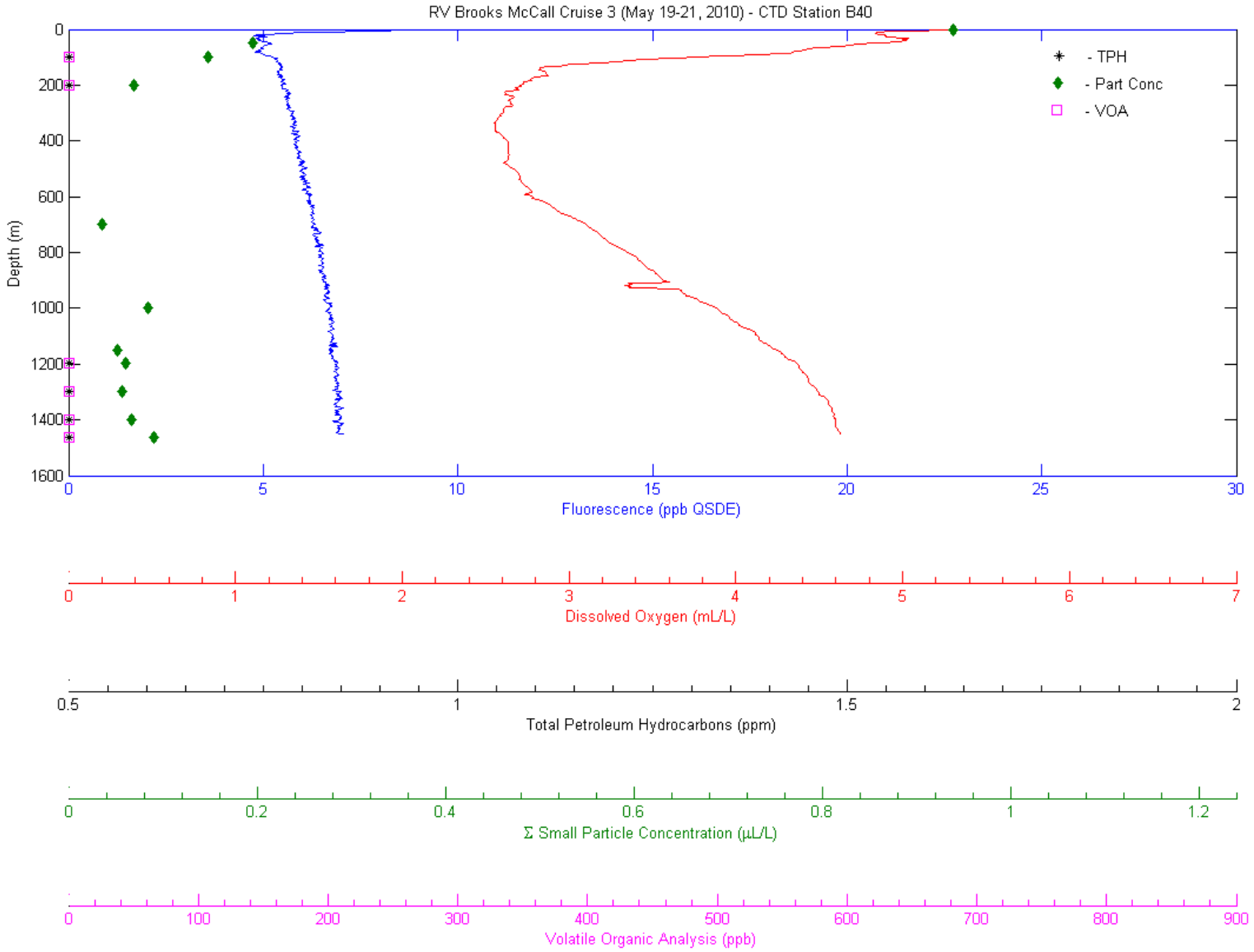


Figure 23. Vertical Profile of fluorescence and oxygen measurements from a CTD cast at station B41 shown with LISST and laboratory analytical data from Niskin Bottle samples.

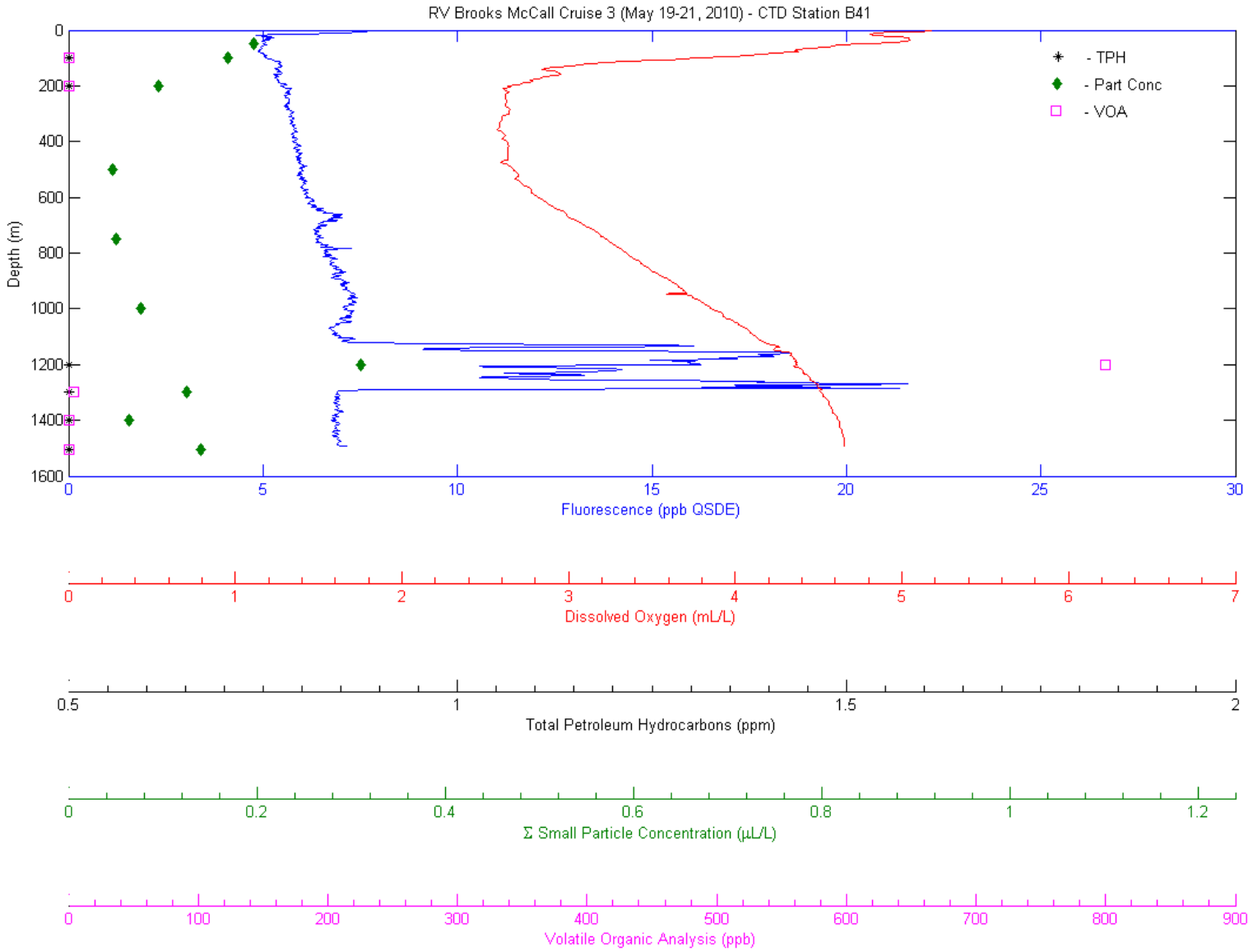
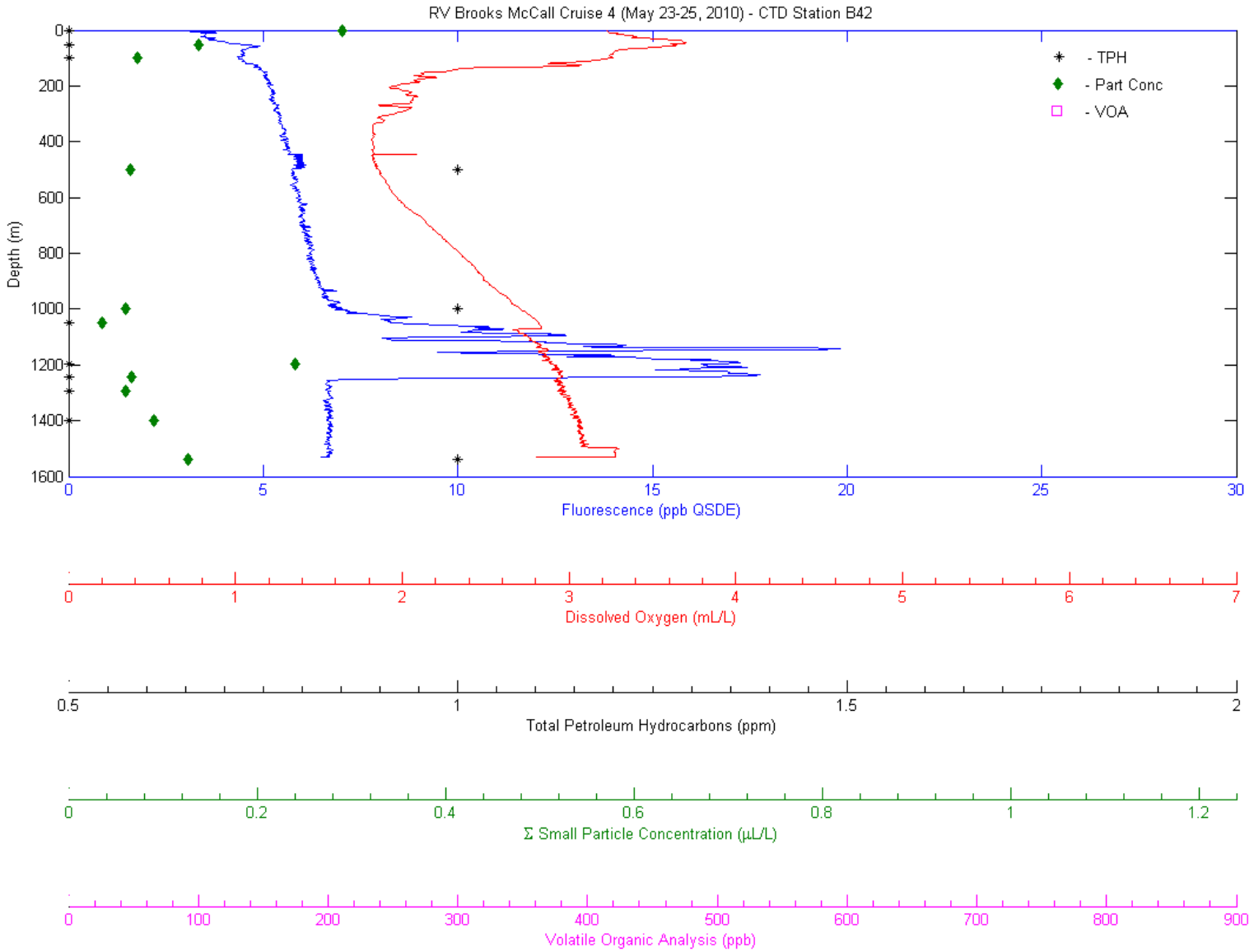
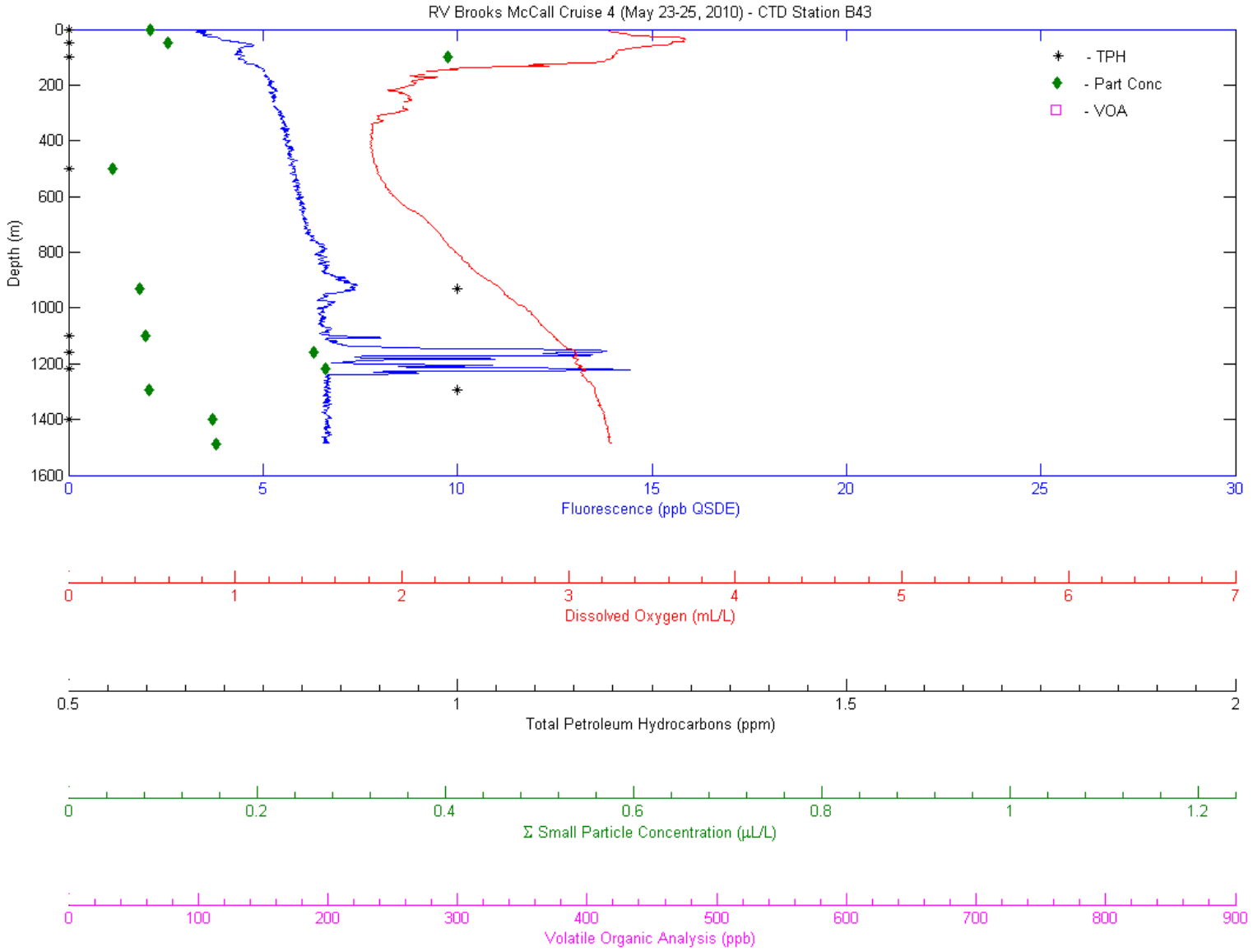


Figure 24. Vertical Profile of fluorescence and oxygen measurements from a CTD cast at station B42 shown with LISST and laboratory analytical data from Niskin Bottle samples.



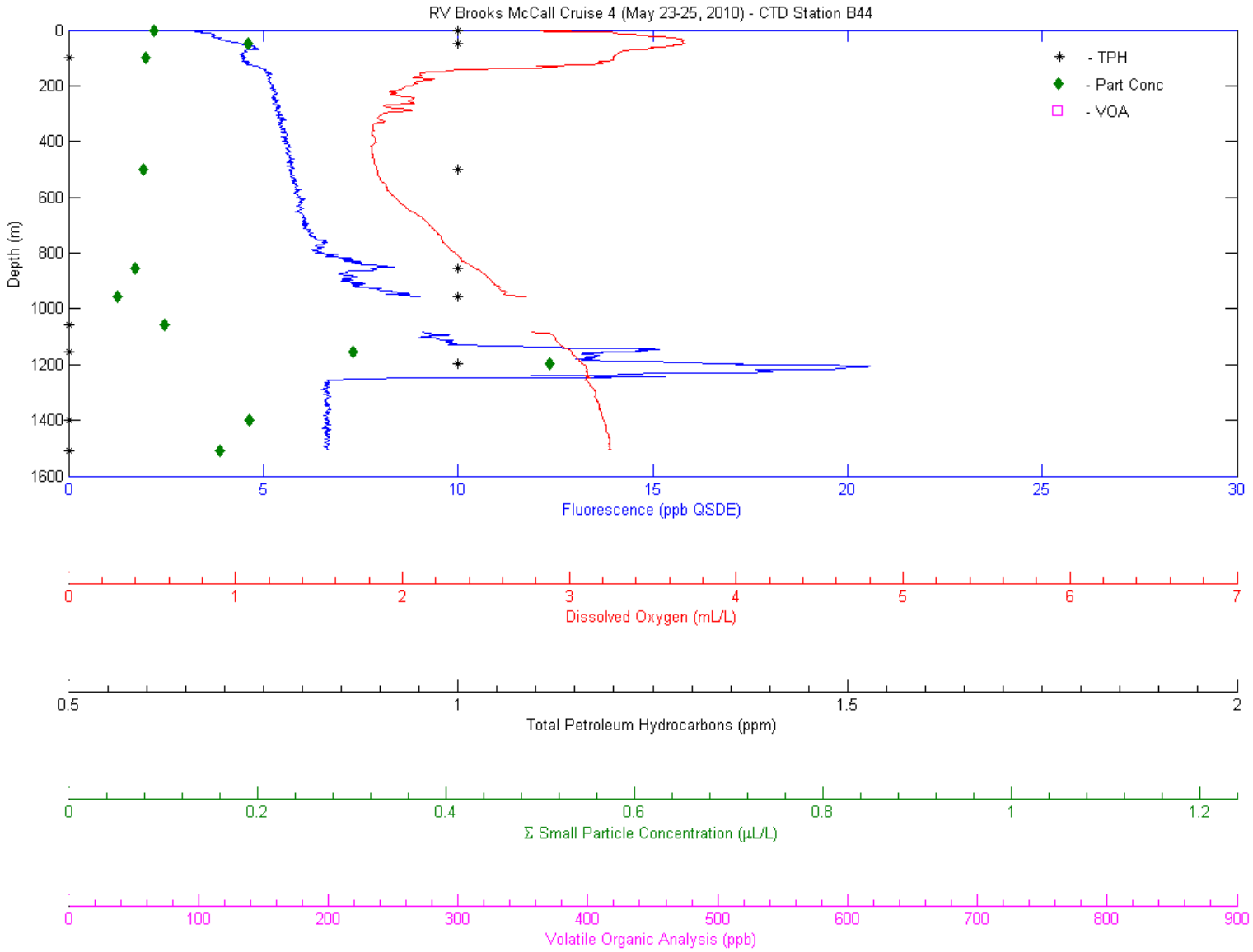
Preliminary Data Subject to Change

Figure 25. Vertical Profile of fluorescence and oxygen measurements from a CTD cast at station B43 shown with LISST and laboratory analytical data from Niskin Bottle samples.



Preliminary Data Subject to Change

Figure 26. Vertical Profile of fluorescence and oxygen measurements from a CTD cast at station B44 shown with LISST and laboratory analytical data from Niskin Bottle samples. There are missing values for fluorescence and dissolved oxygen at 1000m.



Preliminary Data Subject to Change

Figure 27. Vertical Profile of fluorescence and oxygen measurements from a CTD cast at station B45shown with LISST and laboratory analytical data from Niskin Bottle samples.

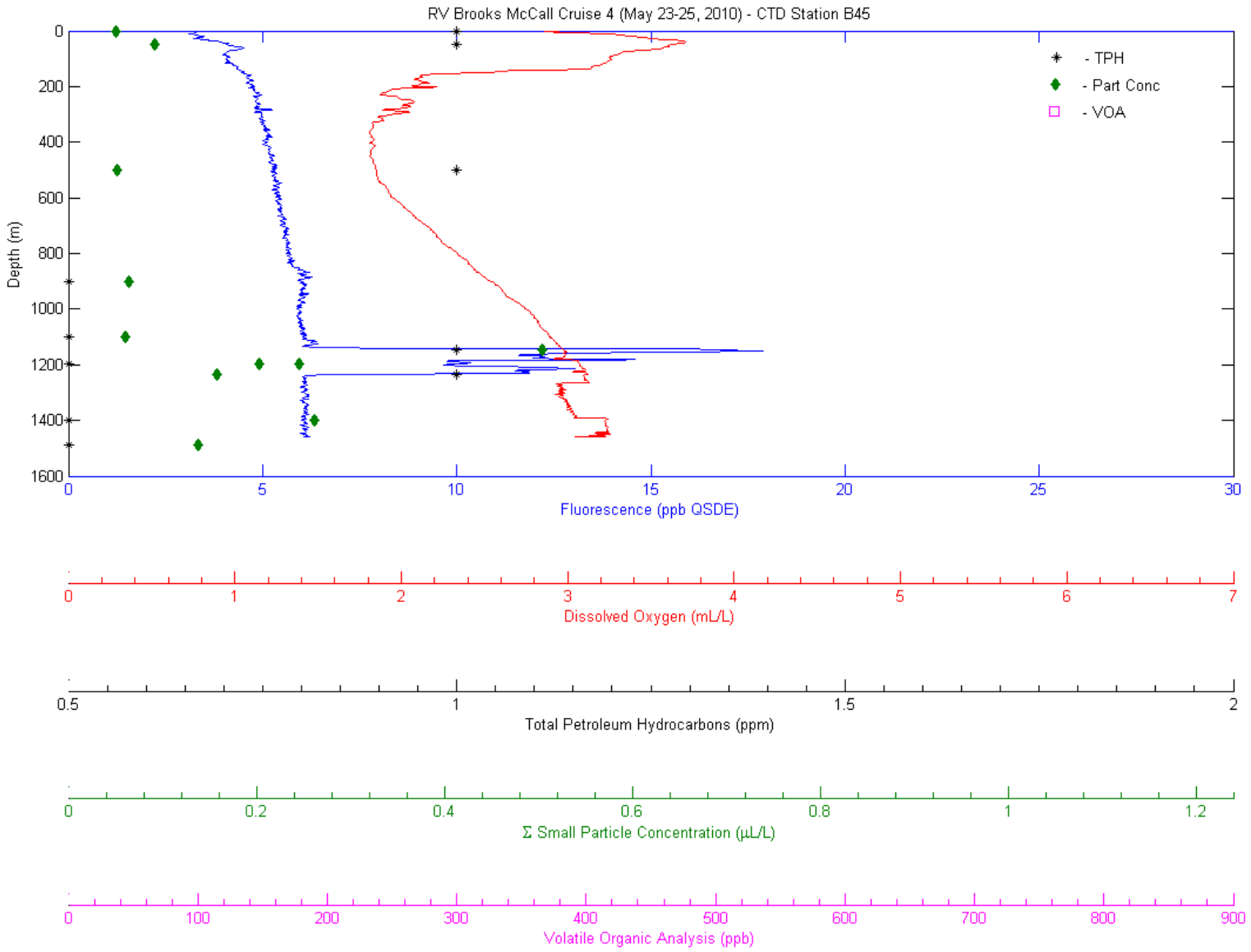


Figure 28. Vertical Profile of fluorescence and oxygen measurements from a CTD cast at station B46 shown with LISST and laboratory analytical data from Niskin Bottle samples.

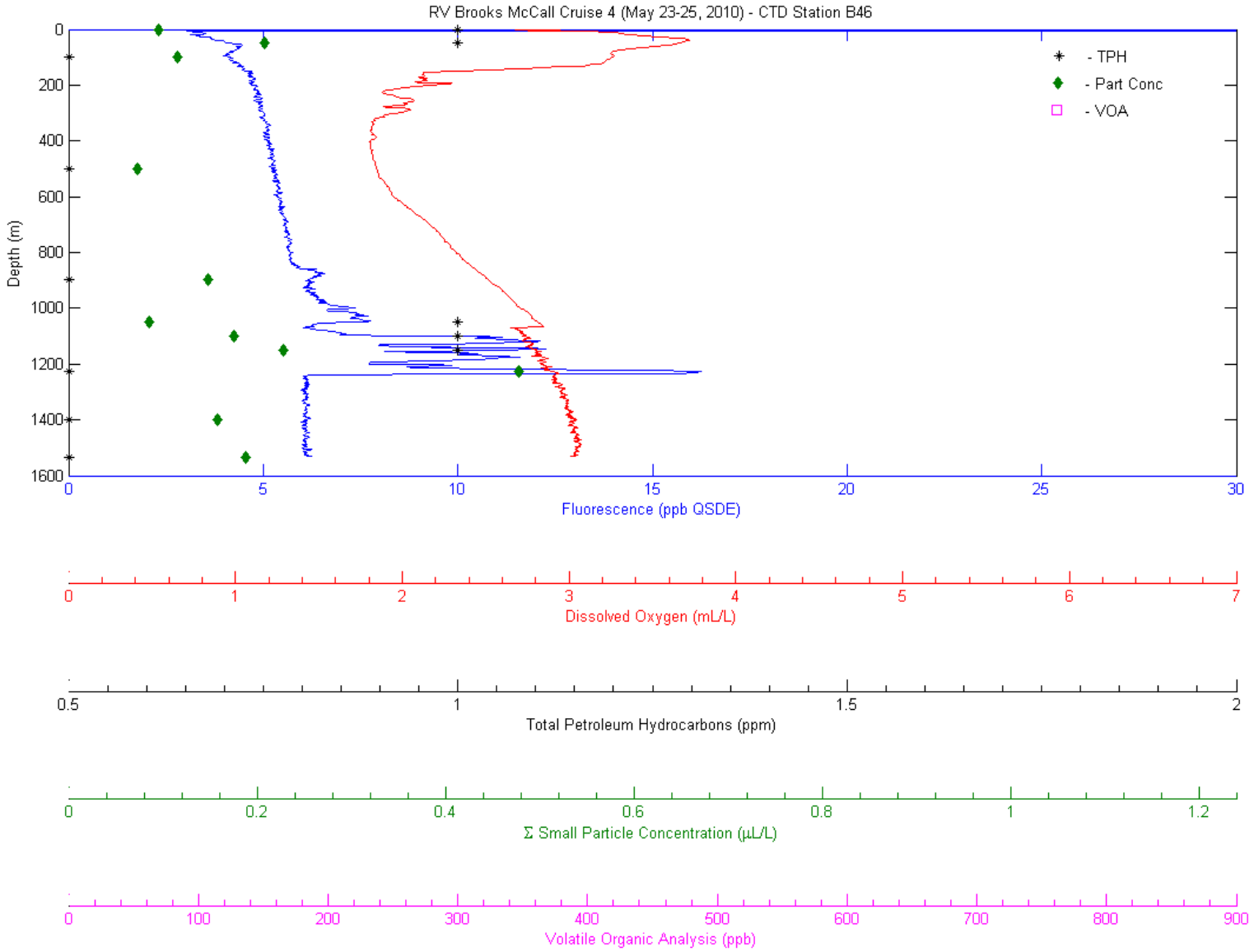


Figure 29. Vertical Profile of fluorescence and oxygen measurements from a CTD cast at station B47 shown with LISST and laboratory analytical data from Niskin Bottle samples.

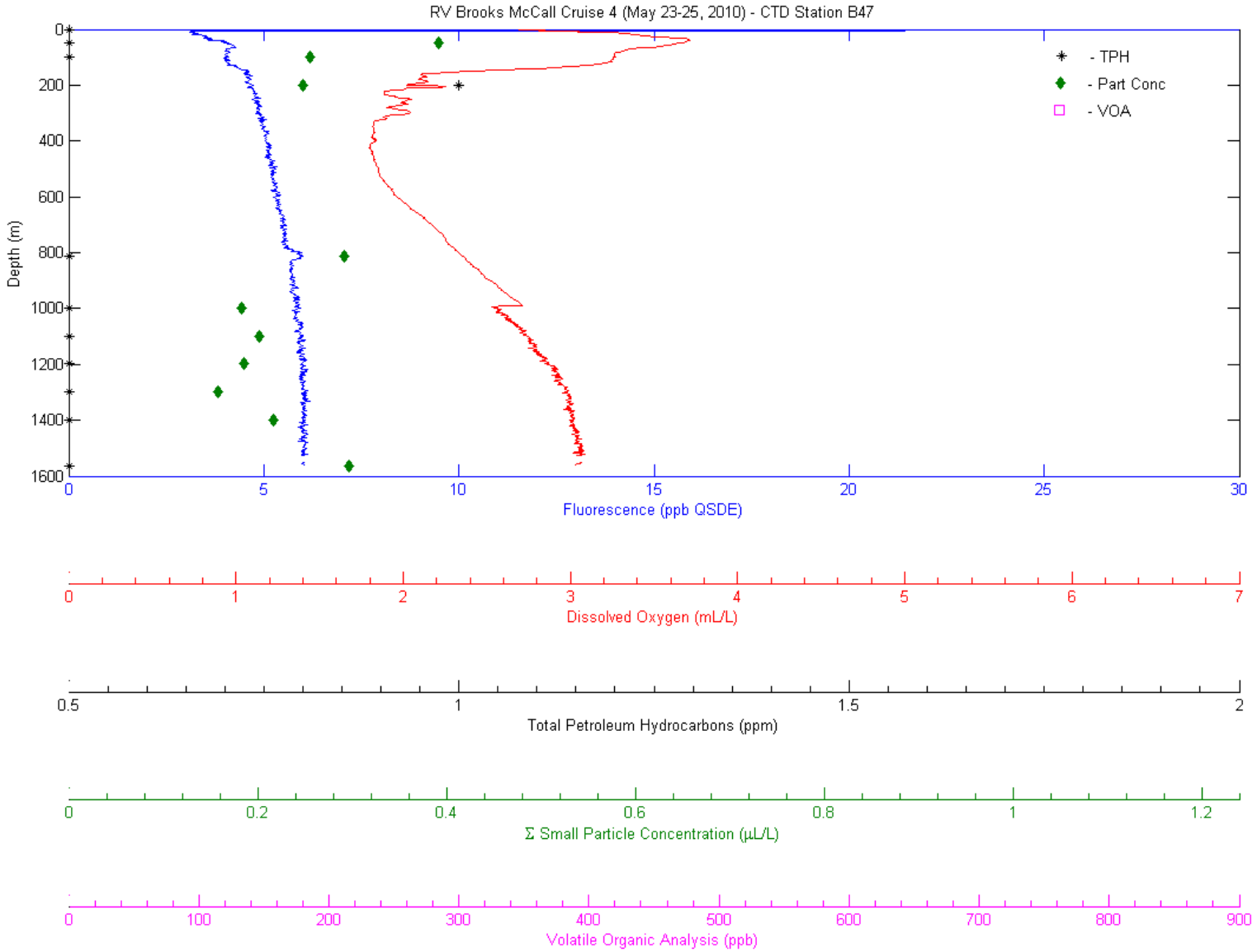
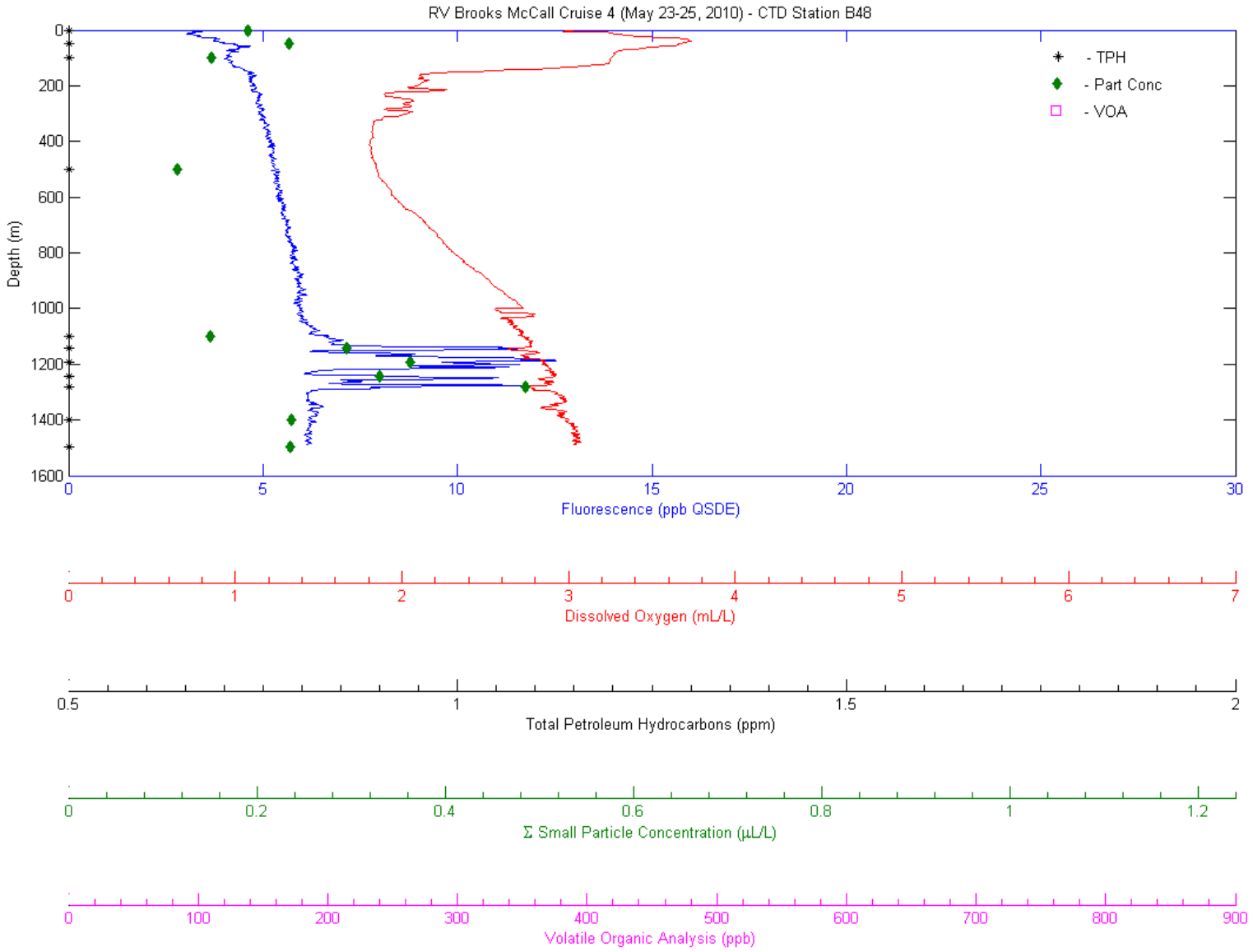
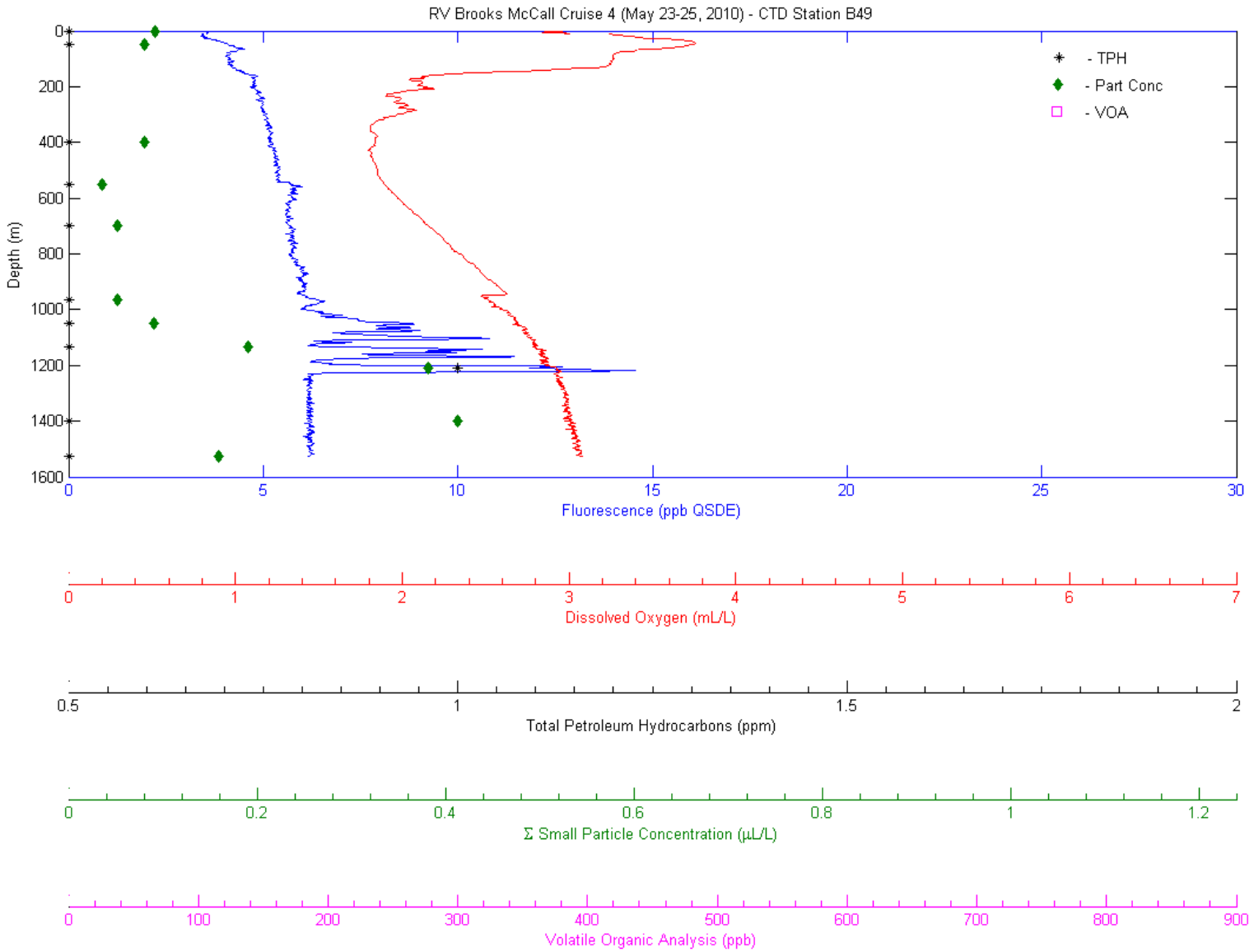


Figure 30. Vertical Profile of fluorescence and oxygen measurements from a CTD cast at station B48 shown with LISST and laboratory analytical data from Niskin Bottle samples.



Preliminary Data Subject to Change

Figure 31. Vertical Profile of fluorescence and oxygen measurements from a CTD cast at station B49 shown with LISST and laboratory analytical data from Niskin Bottle samples.



Preliminary Data Subject to Change

Figure 32. Vertical Profile of fluorescence and oxygen measurements from a CTD cast at station B50 shown with LISST and laboratory analytical data from Niskin Bottle samples.

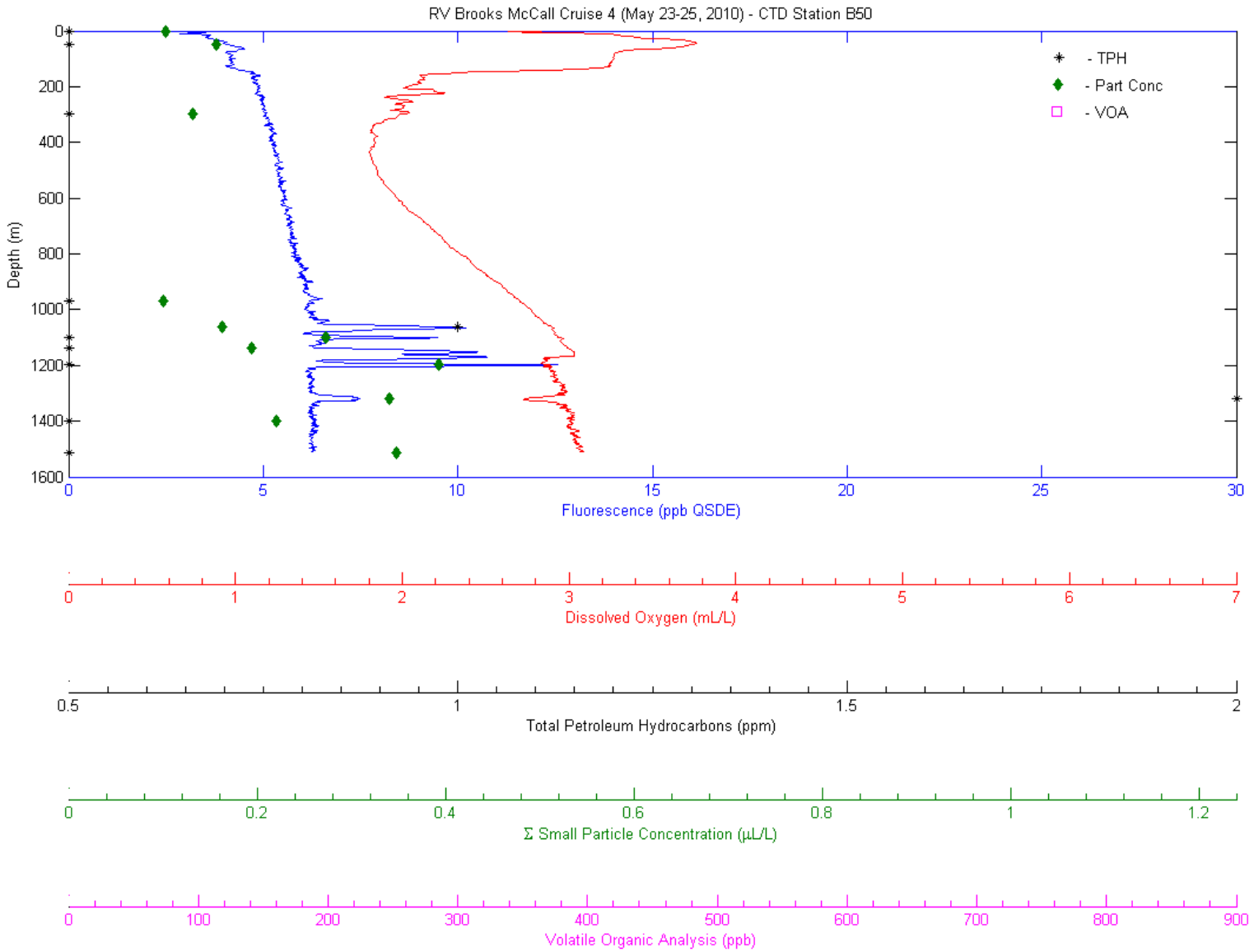


Figure 33. Vertical Profile of fluorescence and oxygen measurements from a CTD cast at station B51 shown with LISST and laboratory analytical data from Niskin Bottle samples.

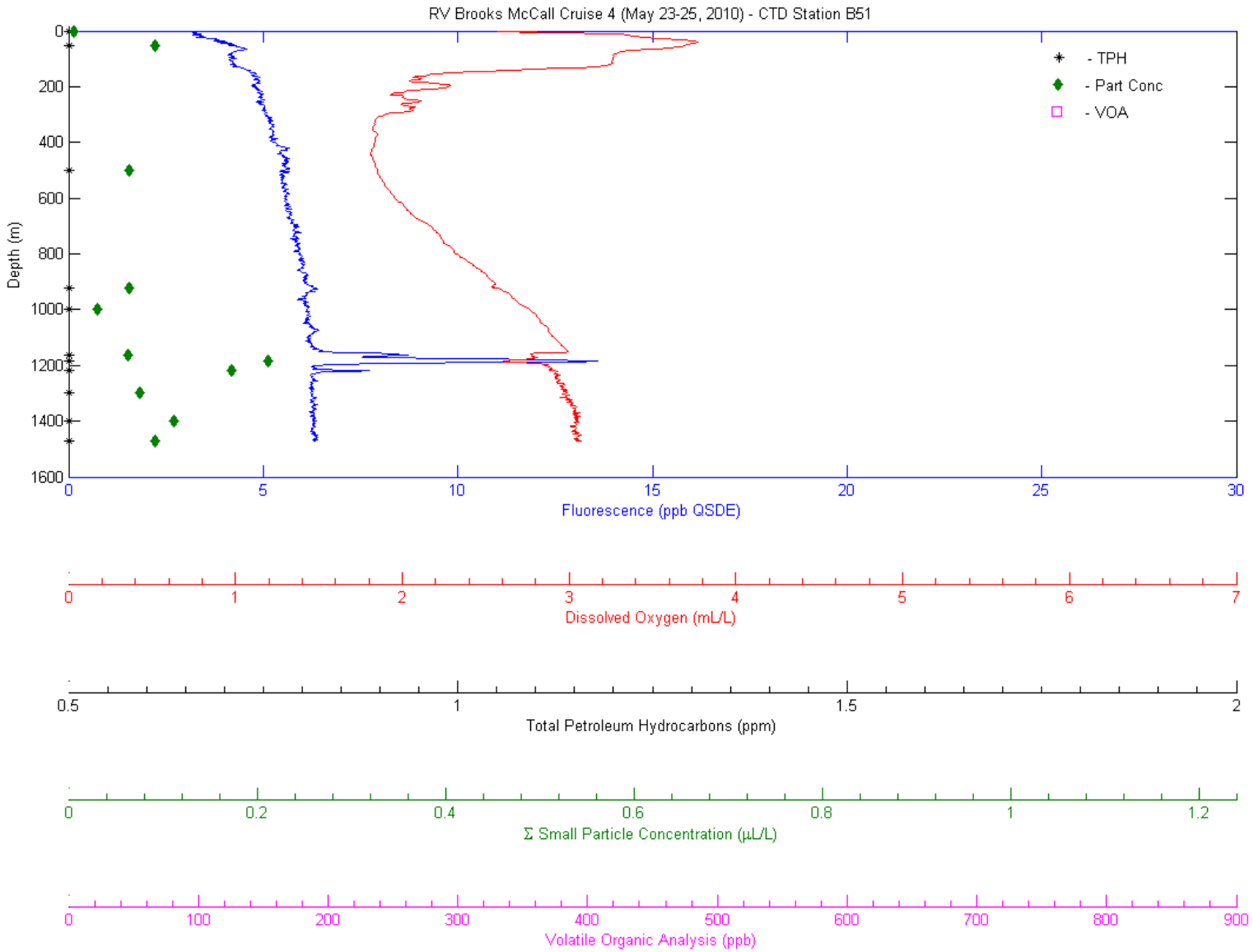


Figure 34. Vertical Profile of fluorescence and oxygen measurements from a CTD cast at station B52 shown with LISST and laboratory analytical data from Niskin Bottle samples.

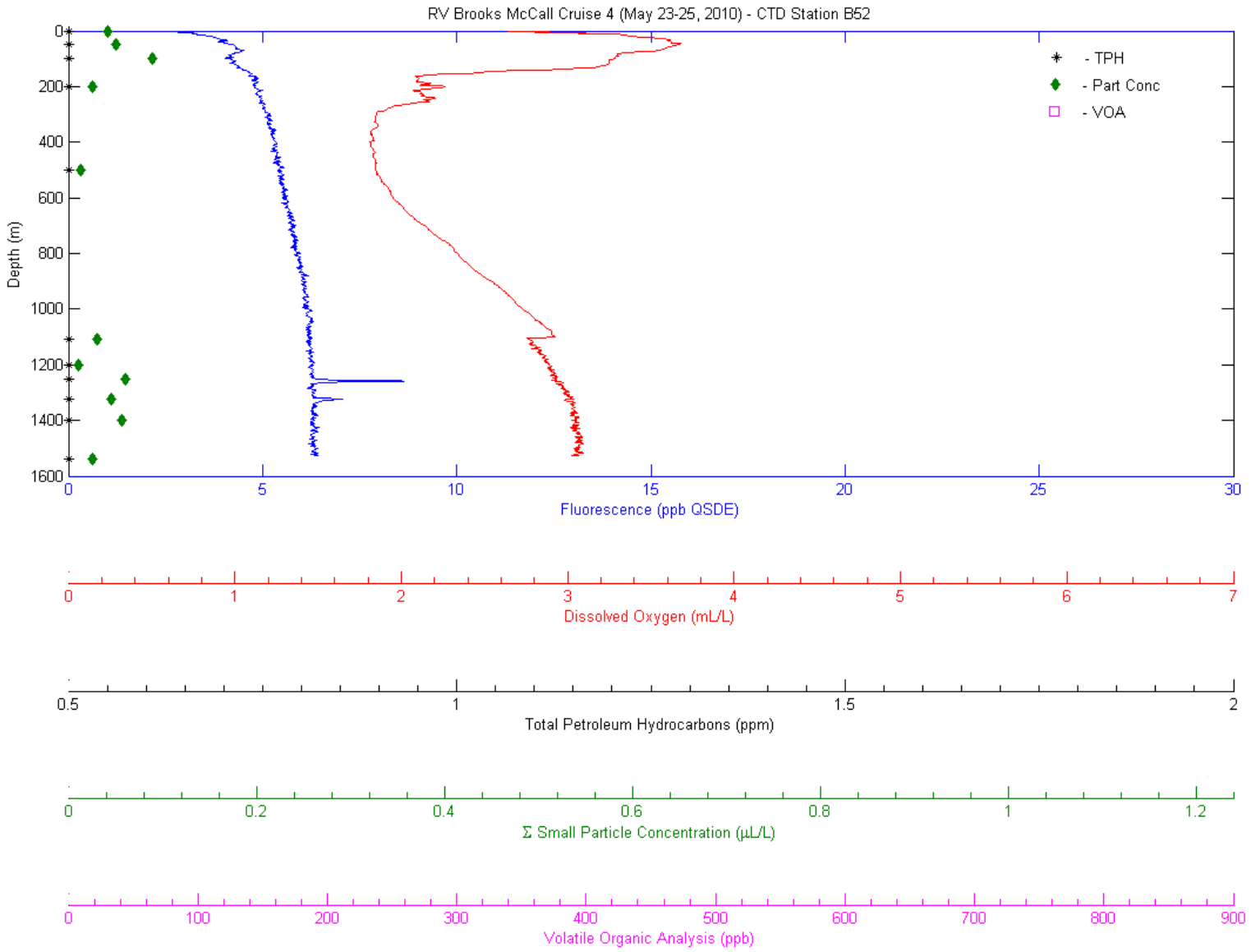
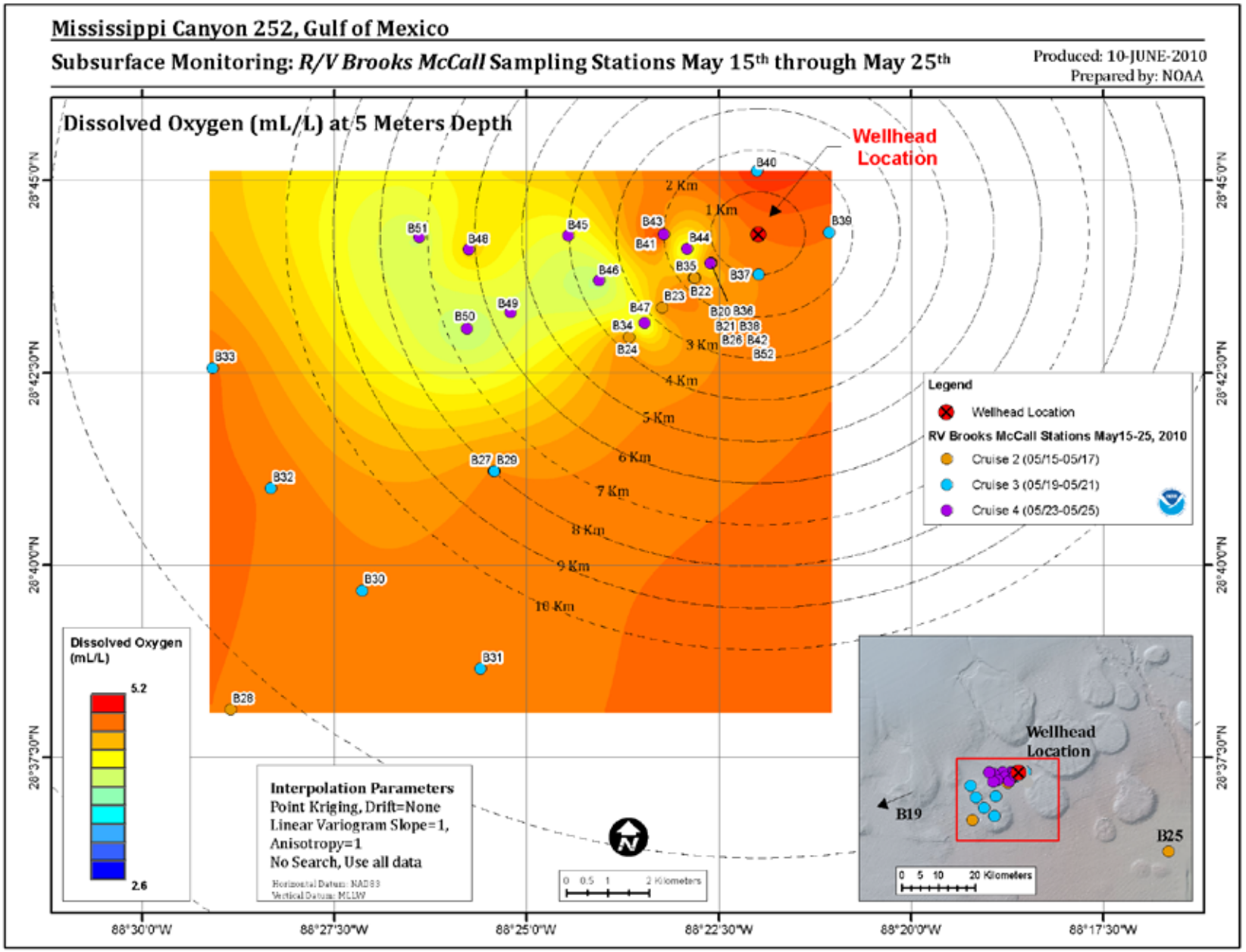
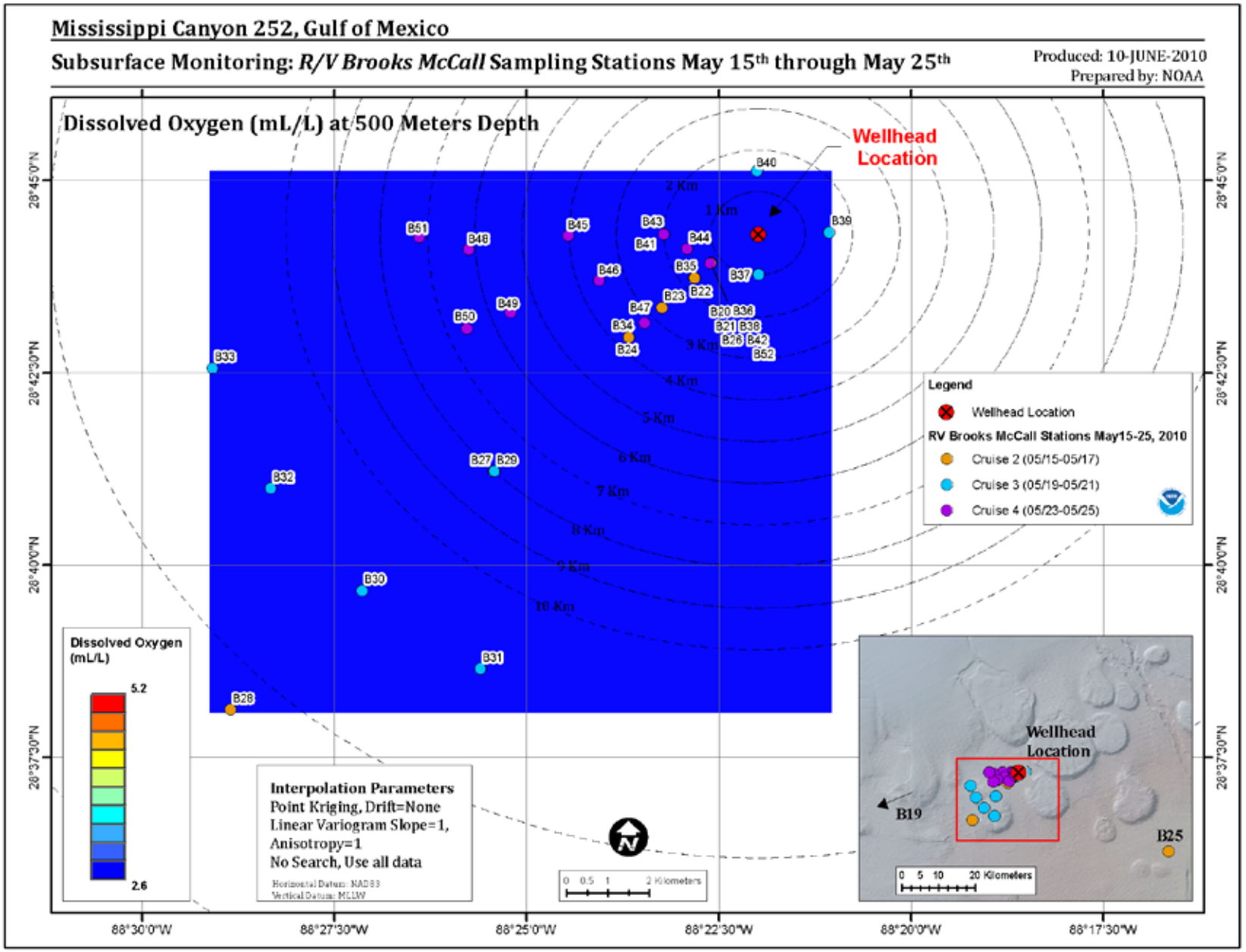


Figure 35. Dissolved oxygen data from cruises 2-4 contoured at 5 meter depth. This figure shows measurements taken over an 11 day period.



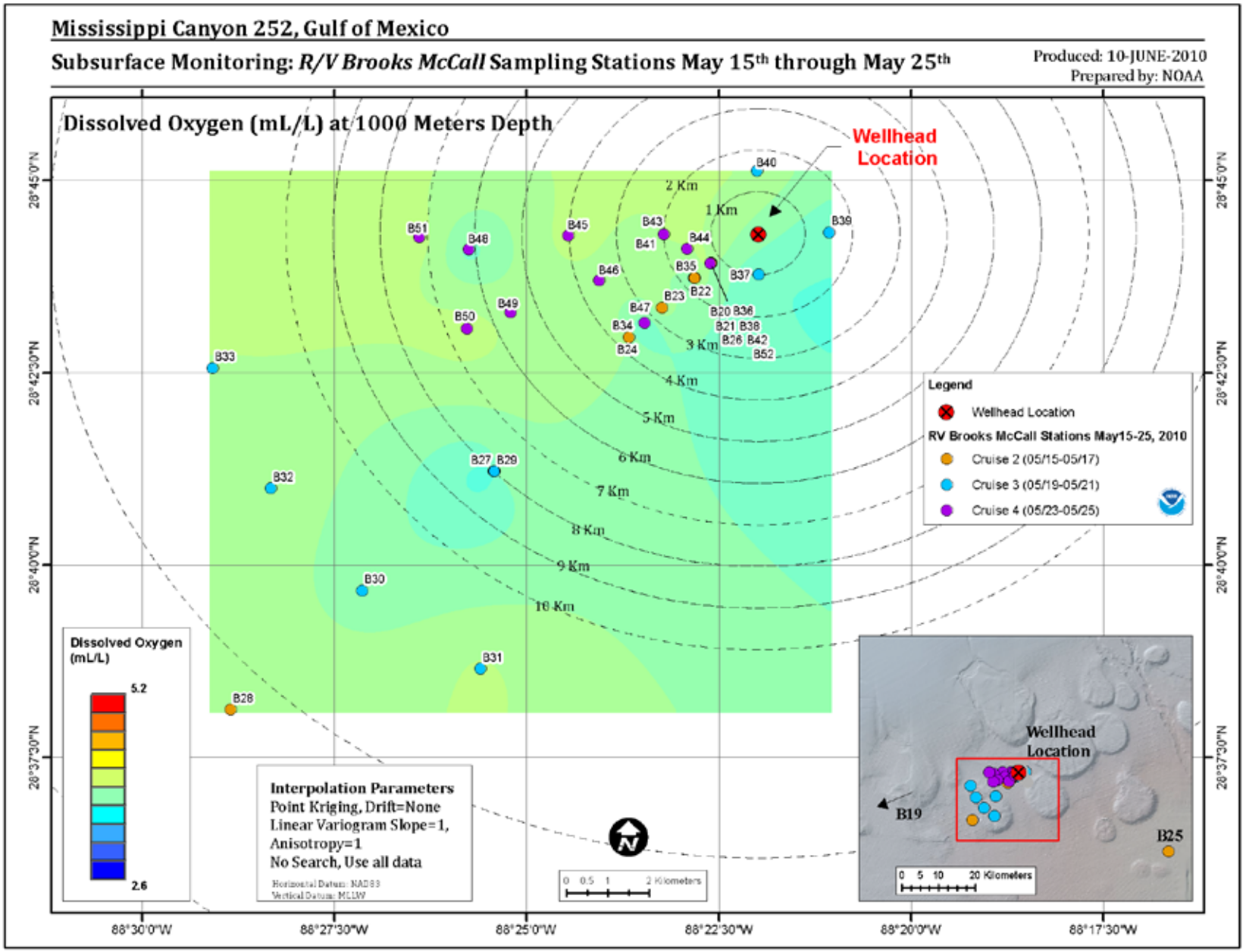
Preliminary Data Subject to Change

Figure 36. Dissolved oxygen data from cruises 2-4 contoured at 500 meter depth. This figure shows measurements taken over an 11 day period.



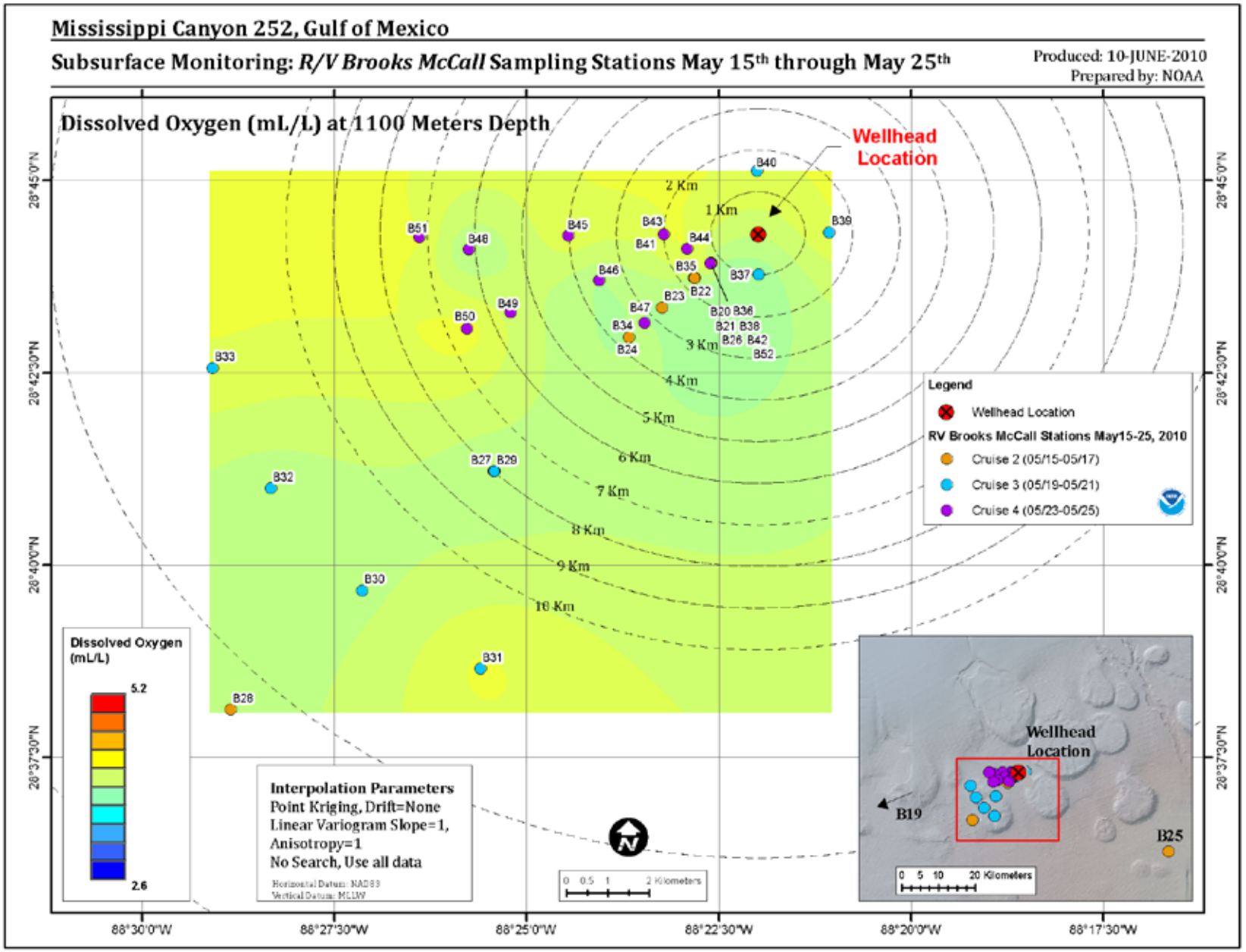
Preliminary Data Subject to Change

Figure 37. Dissolved oxygen data from cruises 2-4 contoured at 1000 meter depth. This figure shows measurements taken over an 11 day period.



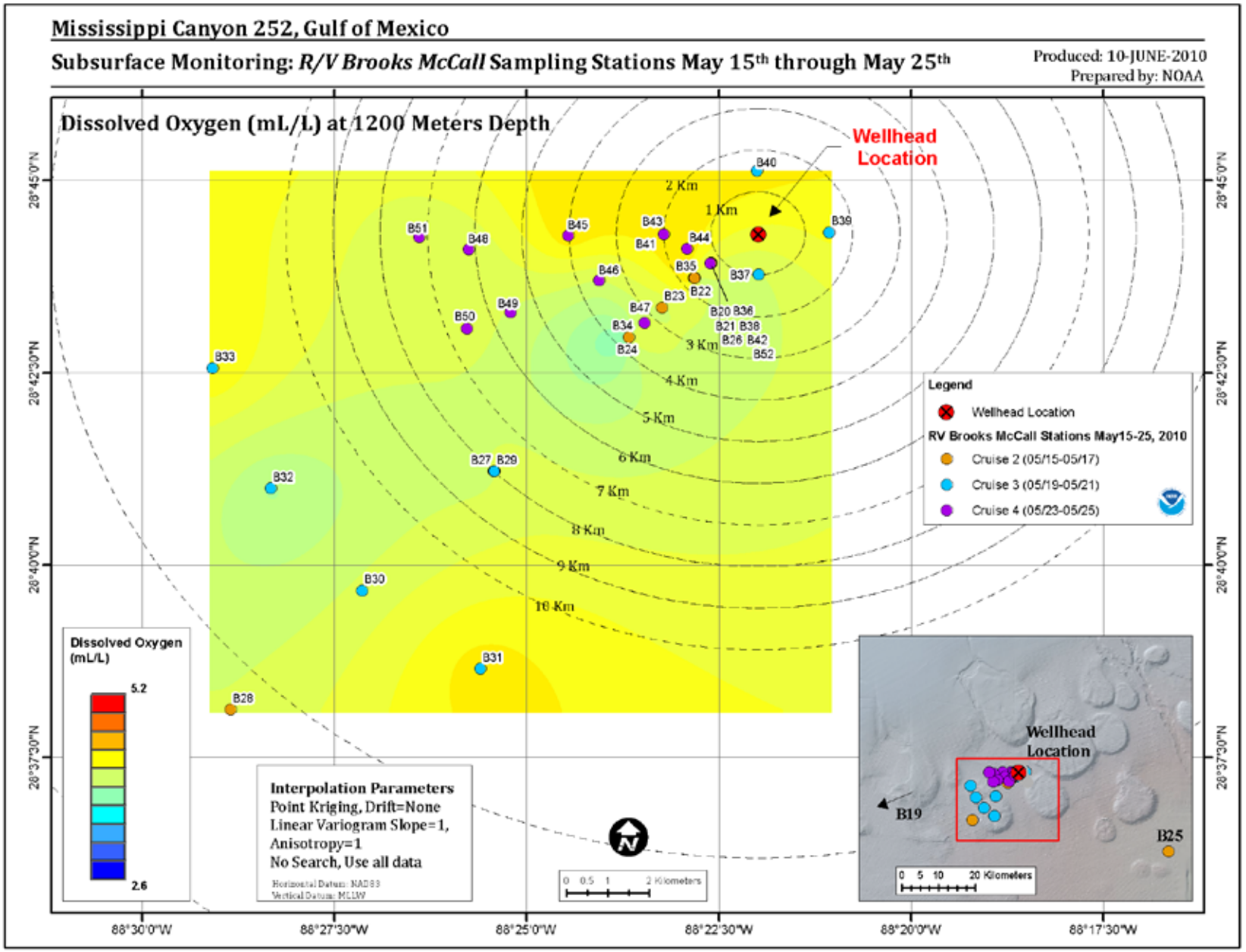
Preliminary Data Subject to Change

Figure 38. Dissolved oxygen data from cruises 2-4 contoured at 1100 meter depth. This figure shows measurements taken over an 11 day period.



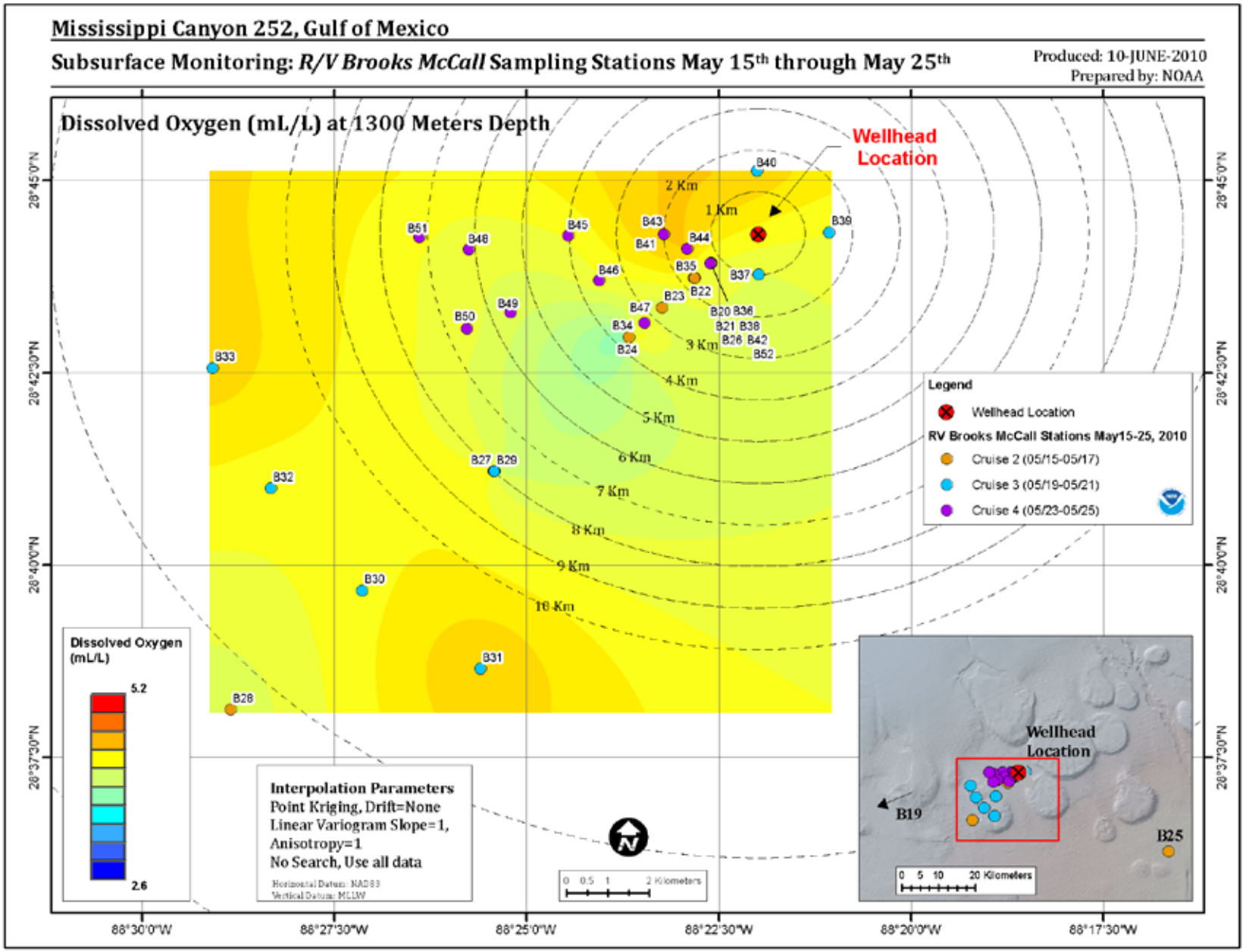
Preliminary Data Subject to Change

Figure 39. Dissolved oxygen data from cruises 2-4 contoured at 1200 meter depth. This figure shows measurements taken over an 11 day period.



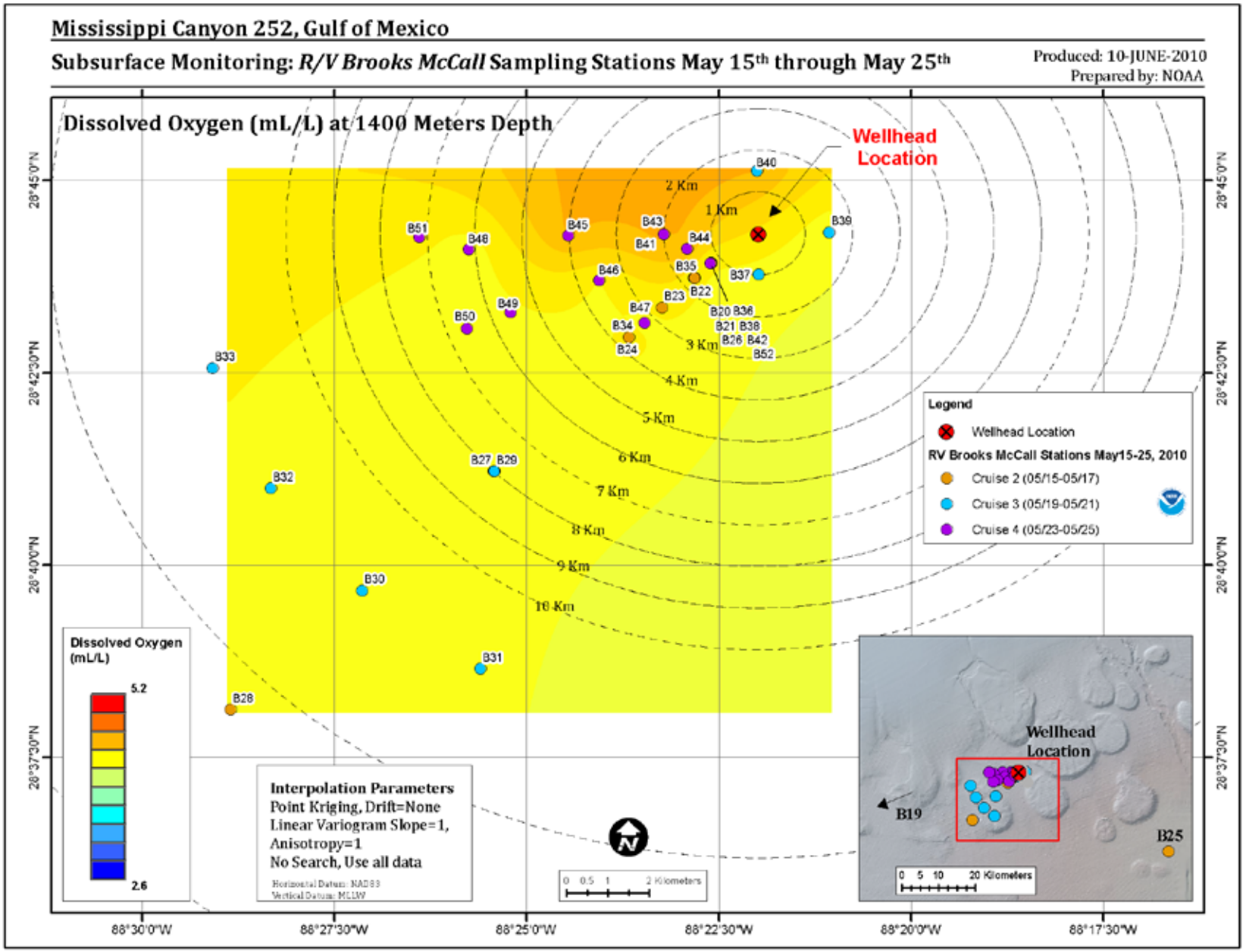
Preliminary Data Subject to Change

Figure 40. Dissolved oxygen data from cruises 2-4 contoured at 1300 meter depth. This figure shows measurements taken over an 11 day period.



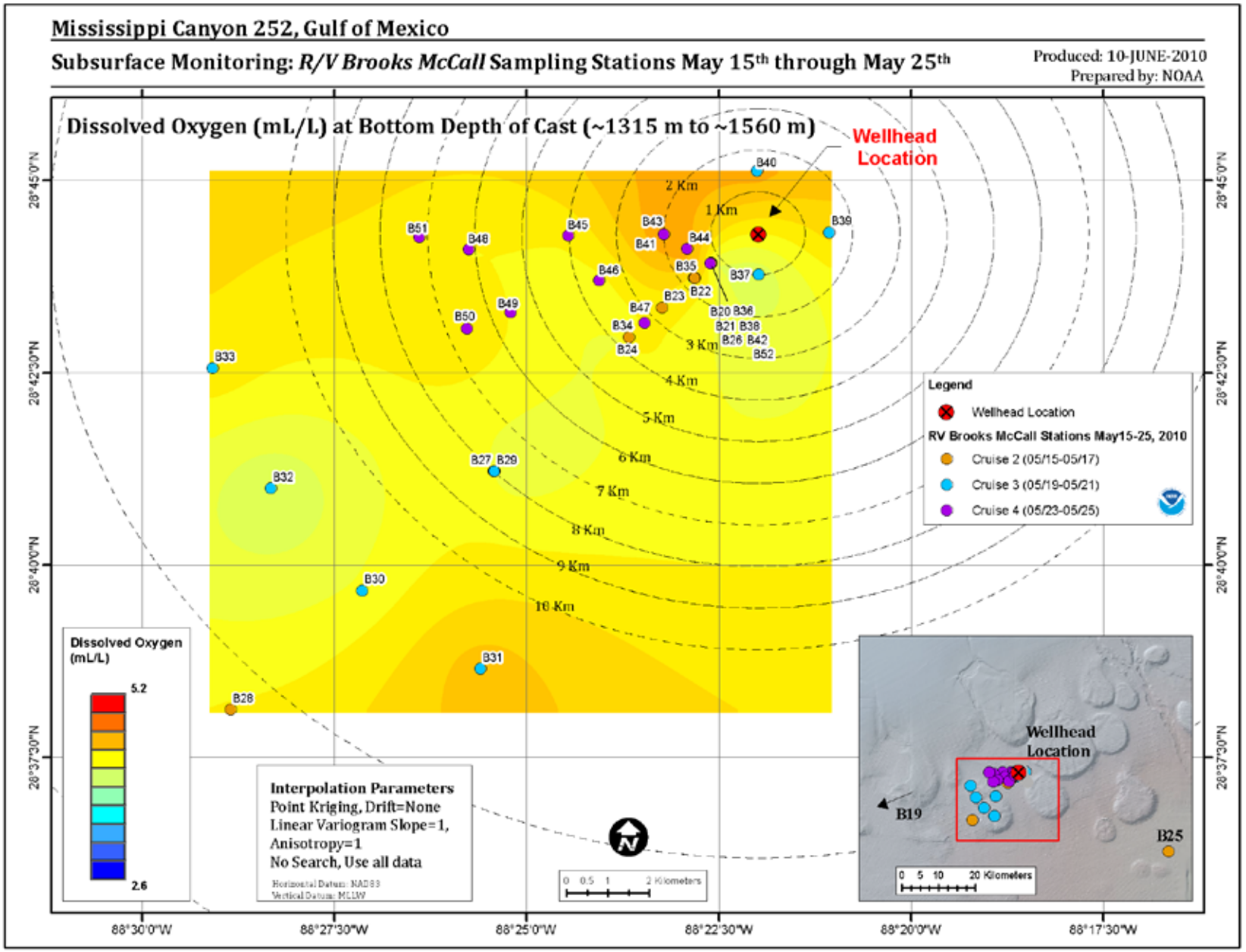
Preliminary Data Subject to Change

Figure 41. Dissolved oxygen data from cruises 2-4 contoured at 1400 meter depth. This figure shows measurements taken over an 11 day period.



Preliminary Data Subject to Change

Figure 42. Dissolved oxygen data from cruises 2-4 contoured at bottom depth. This figure shows measurements taken over an 11 day period.



Preliminary Data Subject to Change

Figure 43. Comparison of RV Brook McCall O_2 data (black plus symbols) with historical May data (red circles) and complete dataset (green circles). The lower trend in waters below 1000 meters is attributed to the anomalous sensor response shown in Figure 44.

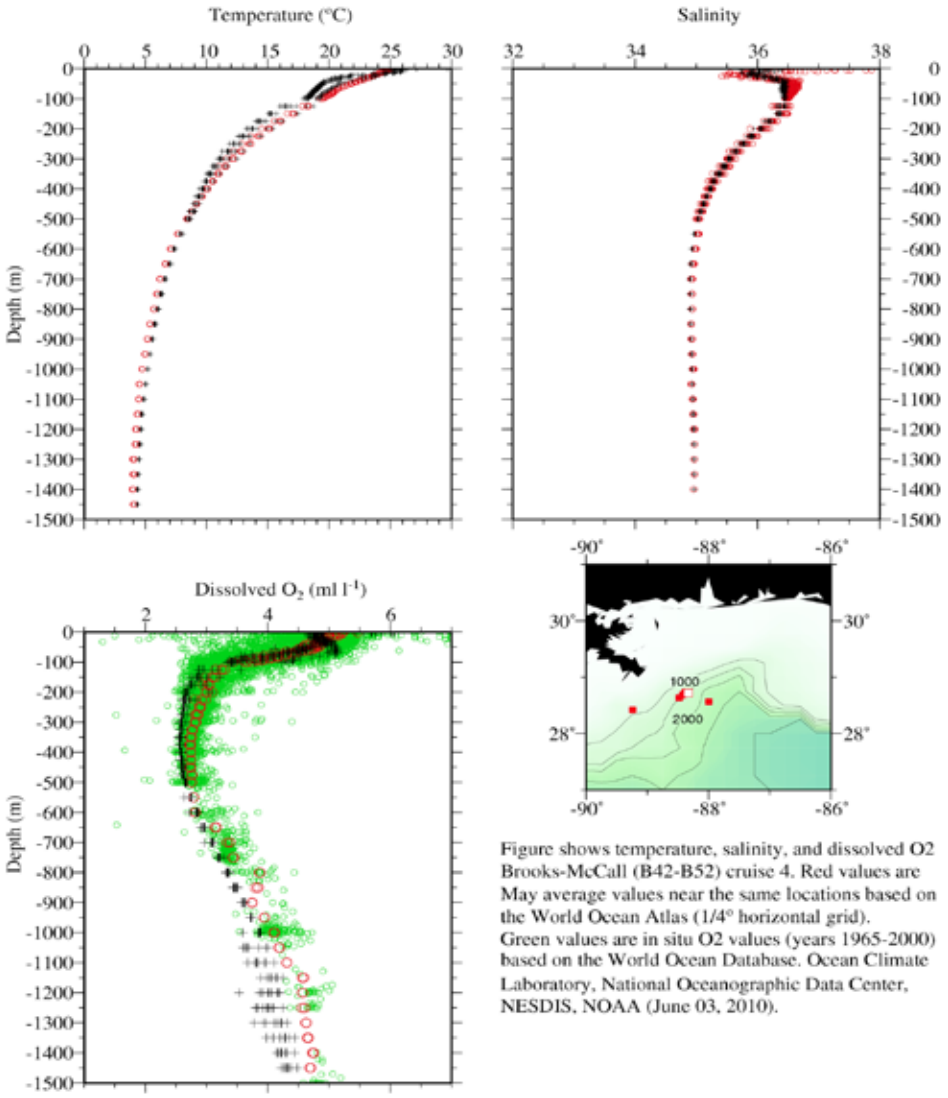


Figure shows temperature, salinity, and dissolved O2 Brooks-McCall (B42-B52) cruise 4. Red values are May average values near the same locations based on the World Ocean Atlas (1/4° horizontal grid). Green values are in situ O2 values (years 1965-2000) based on the World Ocean Database. Ocean Climate Laboratory, National Oceanographic Data Center, NESDIS, NOAA (June 03, 2010).

Figure 44. O_2 and fluorometer trace for station 48 between 1000 and 1500 meters. The sharp peaks in fluorescence at 1150, 1180, 1210 and 1380 m) often correspond to decreases in O_2. The small offset in depth between O_2 and fluorometry is attributed to known O_2 sensor response lag.

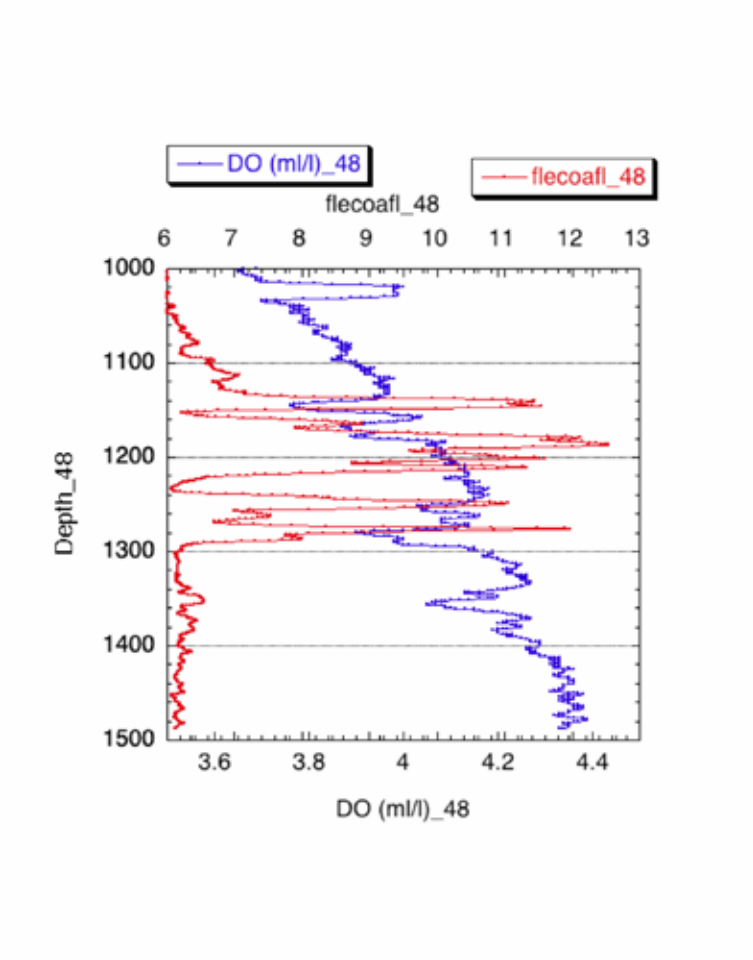
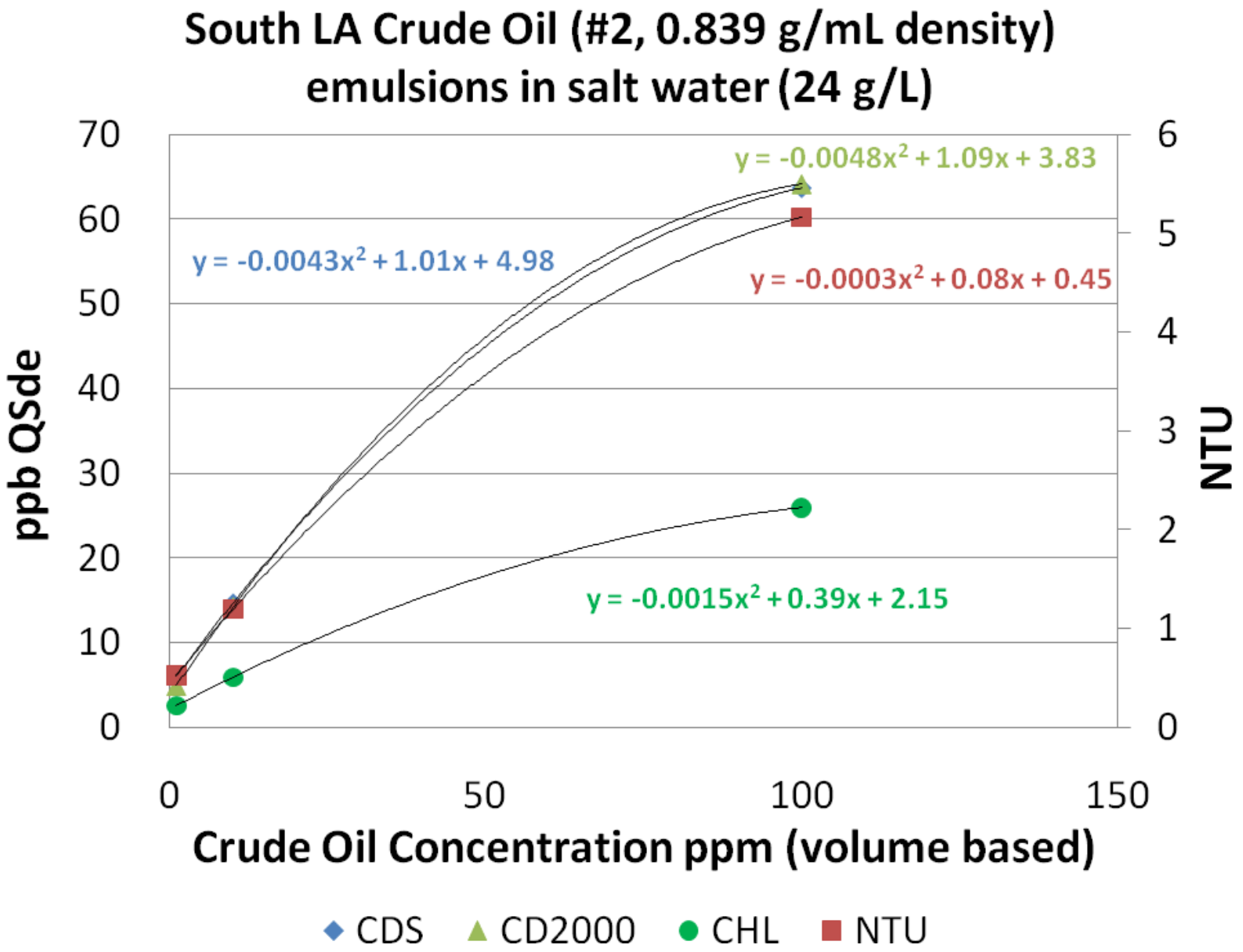


Figure 45. CDOM response curves produced by WET Labs for Louisiana Light Sweet crude oil. Instrument models: ECO FLCDs (CDS); ECO FLCDrt 2000 m rated (CD2000); ECO FLNTU (CHL and NTU). Source: http://www.wetlabs.com/Crude%20Oil%20Lab%20Test%20Client%20UpdateRZ_CK.doc.pdf



Preliminary Data Subject to Change

Figure 46. Composite graph of all processed data for leg 4 (= stations 42-52) of the RV Brooks McCall. The sudden drop in response below 1000 meters is attributed by the authors to sensor malfunction.

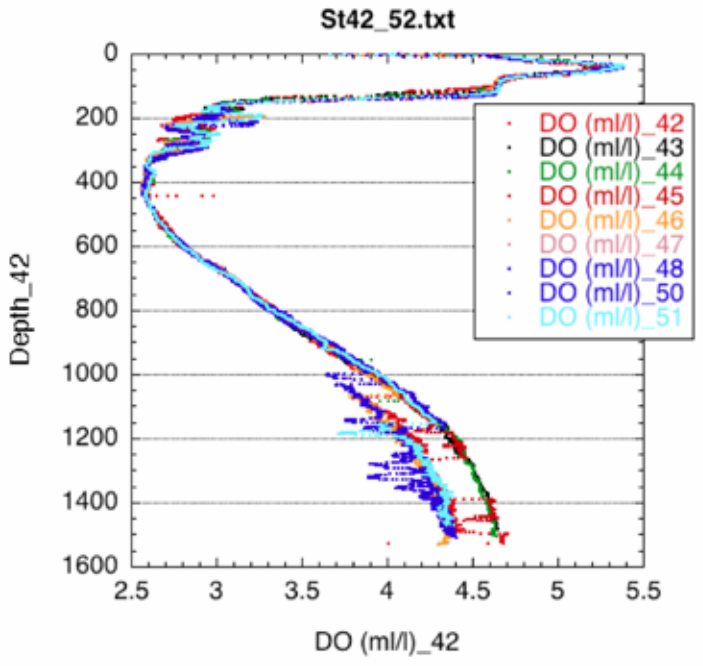


Figure 47. Downcast (blue) and upcast (red) for cast 22 showing the abrupt decrease in sensor response and increase in noise at 1000 m and recovery at 550 meters. The behavior is attributed by the authors to sensor malfunction.